THE SCIENTIFIC MONTHLY

EDITED BY J. MCKEEN CATTELL

VOLUME XLIV
JANUARY TO JUNE

NEW YORK
THE SCIENCE PRESS
1937

THE SCIENCE PRESS PRINTING CO.
LANCASTER, PA.

THE SCIENTIFIC MONTHLY

JANUARY, 1937

SCIENCE IN AN AMERICAN PROGRAM FOR SOCIAL PROGRESS

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THE rôle which science has played in social progress is nowhere more succinctly set forth than in the preamble to resolutions adopted by the American Association for the Advancement of Science, and submitted to the President of the United States in December, 1934:

> WHEREAS, Development and application of science have been basic to the economic and social progress of nations, making possible such movements as universal education, abolition of child labor and slavery, emancipation of women, insurance and pensions, moderate hours of labor and great improvement in the standards of health, comfort and satisfaction in living; and
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> WHEREAS, Scientific developments have not only conferred general benefits, but in particular have been largely effective in leading to recovery from previous depressions—as the railroad industry following the depression of 1870, the electric industry following that of 1896, and the automobile industry following that of 1907; and
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> WHEREAS, Scientific research is a productive investment proven by experience to yield a high rate of return, as illustrated by the saving of $2,000,000,000 per year from the Bessemer steel process and of over $1,000,000 per day from the modern incandescent lamp, and as illustrated also by the entire chemical, electrical, communication, transportation and metallurgical industries and by the enormous employment in such industries;

That our national health, prosperity, pleasure, and indeed our very existence, depend largely upon science for their maintenance and their future development, no informed person would deny. Within our generation this truth has been emphasized, for we have come to the end of free expansion by migration westward, and of free exploitation of ever newly discovered resources of soil and minerals. We have reached the point beyond which further increase in our wealth, population, physical comfort and cultural opportunity will depend not on discovering new resources by geographical exploration but by wiser use of the resources that we now have, through scientific exploration.

This idea is not new, but I doubt if we realize its profound significance; it marks a turning point in the history of the world! How did the Egyptians, the Greeks and the Romans secure their wealth? By plunder and taxation of conquered nations and by "labor-saving" production through the work of enslaved peoples. How were the great commerce and wealth of England acquired? Through geographical exploration, conquest and colonization of virgin lands with such returns in wealth as we find it hard now to comprehend. For example, the profits of the British East India Company were of the order of 100 per cent. on each voyage of its merchantmen.

Now all livable portions of the world are settled and closely interconnected by travel and trade. Probably the Italian conquest of Ethiopia and Japan's expansions into China are about the ending of the centuries old struggle for wealth through territorial conquest. In our own country, Horace Greeley's advice "Go west, young man, go west" no longer has its original significance. The geographical pioneer is now supplanted by the scientific pioneer, whose thrill of discovery or urge for reward is no less keen and whose fields of exploration are probably unlimited. Without the scientific pioneer our civilization would stand still and our spirit would stagnate; with him mankind will continue to work toward his higher destiny. This being so, our problem is to make science as effective an element as possible in our American program for social progress.

Practically all scientific work in the United States is carried on under one or another of three auspices—the government, industrial organizations, and educational institutions or similar altruistic foundations. The scientific services of the Federal Government are spread through forty bureaus, of which eighteen are primarily scientific. There are about 630 colleges and universities in the United States, including 155 engineering schools. There are upwards of 1,600 research laboratories operated by industrial companies. Watson Davis, of Science Service, recently estimated the total annual national expenditure in scientific research work as about $100,000,000, divided roughly equally between government, educational institutions and industry. Each of these three categories of scientific work has its proper scope, limitations and opportunities. Each has its peculiar problems of operation. I will proceed, therefore, to discuss them separately.

Science in Government

During the two and a half years of its existence, terminating last December, I had the extraordinary opportunity to serve as chairman of the Science Advisory Board, under which, with its subcommittees, more than a hundred of the country's ablest scientists and engineers gave free and devoted service to the scientific interests of the government at the request of the President. Out of this experience I could draw a kaleidoscopic picture of the scientific work of the government: work of vast importance to the welfare of the country; staffed by an army of able scientists single-mindedly devoted to their respective jobs; financed by less than half of one per cent. of the total governmental budget; replete with duplicating and uncoordinated effort; subject to the charge that many projects are started, but few are ever stopped; with partisan loyalties to bureaus and departments continually blocking attempts at changes in organization even when there is no disagreement as to the improved efficiency that would thereby be gained; with almost no executive officers, more permanent than the current administration, to coordinate the various bureaus, direct their programs and plan their future; yet with sincere and often courageous concern on the part of department secretaries for the efficient working of the bureaus under their jurisdictions; and under all these conditions a surprisingly effective service; these are some of the facets of this kaleidoscopic picture. (In these remarks I except the two military departments, which are organized on a more permanent basis.)

This is not the occasion to discuss the specific problems which were referred to the Science Advisory Board, which were technical problems of organization, scientific programs, budgets or personnel. Suffice it to say that there was generally

good cooperation from high officials from the President down and that there was much actual accomplishment, reflected in the present and pending operations of a number of the scientific bureaus, despite regrettable failure to achieve results in some important matters. But of greater significance than these specific jobs was the development in the minds of the board of a certain conception of the rôle of the government in science which I can not present better than by quoting certain passages from the final report of the Science Advisory Board to the President:

An absolute prerequisite to (our national) welfare, independent of political theories and basic to attempts at national planning or improvement of any kind or degree, is adequate scientific information regarding the materials and forces with which great groups of our population have to deal. This is the justification for the existence of scientific bureaus in the Government.

In a democracy like ours, designed to safeguard personal liberty and to stimulate individual initiative within the framework of "general welfare," there is no need for the Government to embark upon comprehensive programs in pure science, invention or industrial development. There are, however, numerous scientific services of such wide scope and universal utility that no agency except the Government is competent adequately to handle them. (In this category are public health, weather forecasting, topographic mapping, development of scientific and technical standards, mineral surveys and statistics, safety codes, patents, soil science, improvement of crops and live stock.) There are other scientific services which are essentially supplementary to non-scientific governmental activities. (Among these are engineering work relating to flood control, water supply and aids to navigation; scientific aids to national defense; development of standards for the purchasing of supplies for use of governmental bureaus.) There are also fields of scientific or technical development which hold evident promise of benefiting the public but which are not proper or practical fields for private initiative (such as the activities of the National Advisory Committee for Aeronautics, and the financial aid to land grant colleges for development of agriculture and engineering arts). In these three categories and in this order of importance lie the proper scientific activities of the Government.

The first scientific bureaus to be established had to concern themselves but little with the coordination of their programs. Each filled a definite need and its purpose was to gather facts in a designated field. (These federal services, however, have expanded enormously with the increasingly complex demands of our civilization.) Side by side with the growth in the number of bureaus and in the multiplicity of their functions, there should have been applied (more rigorously) the principle of coordination of related work, no matter in what bureaus the work may be done. (This is a primary requisite for efficiency.)

Freedom of scientific work from political or policy-making influences is a second prime consideration. Whatever the trend of social or political thought and whatever the degree of national planning, the people of the country have the right to expect that the scientific services are always free to report and interpret the facts in a given field of inquiry as they find them and not as the government of the day may wish to have them reported or interpreted. (They) should be free to produce results that are not discolored by the opinions and snap judgments of policy-making political groups who may wish to put the dignity of "science" behind their plans in order to win public approval.

Over and above the work of particular scientific bureaus, there is increasing activity on the part of the Government in undertaking large projects whose feasibility or justification are matters for technical decision from many points of view: scientific, economic, humanitarian. Examples of such projects are: irrigation, power development, flood control, soil erosion control, shelter belt, waterways, retirement of sub-marginal land and colonization. Where huge sums are involved and large groups of people affected, it is more than ever necessary that decisions and policies should be settled only after the most thorough, competent and disinterested study of such questions as: Is the project technically feasible? Will it accomplish its purpose? What are the alternatives, and has the best plan been selected? Will the benefits justify the expenditure? For technical advice on such questions, Congress and the Executive Departments should have ready access to, and should use, the best talent available both within and outside of the government services.

It is (therefore) the concern of every citizen that there be available to government the most competent and impartial advice which can be

found. The endurance of our traditional form of government will depend in increasing measure upon the quality of expert judgment, tempered with experience, which is available to government, and the willingness of government to follow such judgment.

Considerations like these led the Science Advisory Board to recommend to the President the permanent establishment of a scientific advisory council, its members to be nominated by the National Academy of Sciences and to serve without pay, but with provision for necessary travel and secretarial expenses. This council would be enabled to appoint subcommittees on the principal scientific bureaus. The duties of this group would consist, first, in assisting the bureau chiefs to formulate general programs and policies; second, in promoting coordination and working against improper duplication of effort of the various bureaus; third, in interpreting, criticizing or defending the work and plans of the bureaus before the responsible department secretaries and congressional committees; fourth, in giving to the director of the budget its critical and independent judgment, (advisory only), regarding budgets and requests for appropriations for scientific work in the non-military departments.

It is my conviction, shared by my engineering and scientific colleagues who have studied the situation during the past three years, that some such plan would be feasible, and that it would do more to increase the efficiency and the prestige of the federal scientific services than can be achieved in any other way. It may be that thought of such an independent and sometimes critical advisory service is not relished by any official who is more concerned with maintaining his unlimited authority than with ensuring efficient conduct of the people's business for which he is responsible. But when I heard a high official say that "of course the plan is impractical," I thought to myself that this only means that he and some of his colleagues do not like it. Plans similar to the one here proposed have been in successful operation in several European countries in recent years. In Great Britain, for example, a group of the Empire's greatest scientists act as official advisers to the privy council on all questions of programs and budgets for scientific work under governmental auspices.

Science in Industry

Turning now to industry, we have no difficulty in defining its proper scope of scientific research: that type of research is justified which shows reasonable promise of producing better products or desirable new products which can be made and sold with profit or of reducing the cost of existing products. Within this simple definition, however, lies great scope for informed judgment, courage and skill in the decision as to "what constitutes reasonable promise?" and "how great is this promise in comparison with the probable cost?" It is the action on such questions that largely determines the future growth or decay of an industry.

Experience has convinced progressive industries that as much as several per cent. of income can profitably be spent on research. This expenditure is both an investment for future dividends and an insurance against future loss through obsolescence or more enlightened competition. Dr. Robert A. Millikan emphasized the investment aspect when he said: "Research pays because you know what you want, go after it with informed brains by the scientific method, and in general get it: But it often yields (extra) dividends because you get something more that you didn't go after." And Francis Bacon, over three hundred years ago, described the fate of the industry which neglects research when he wrote: "That which man altereth not for the

better, Time, the Great Innovator, altereth for the worse." The statement is not unusual which was made a few years ago by the president of a great manufacturing company when he told his stockholders that 60 per cent. of sales that year had been of products that ten years before were unknown.

Several years ago the National Research Council compared the financial health of industries, as a function of their activity in research, as measured, for example, by relative expenditures for research. At the top were such industries as the chemical, electrical, communications and automotive; toward the bottom were railroads, lumber and textiles. The correlation between support of research and financial prosperity was decidedly striking and has been an effective object lesson.

In any attempt to make science more effective in industry and through it more helpful to the public, certain obstacles must be met and overcome.

First I would mention the so-called "hard-headed practical business man"; a man without vision, imagination or enthusiasm for new things; a man who scoffs at theory or a college degree; a man whose sole criterion of proper practice is that which he has been accustomed to in the past; a man who spends as little as he can on research in order that his profits day by day may be larger. The withering policies of such men have driven many a flourishing business into obsolescence. If, by accident, a research laboratory has been set up in this man's company, its staff will be among the first to be fired in a depression, thus saving temporarily dollars but losing permanently the capital investment in trained intelligence.

In this same class I would place that type of control, sometimes exercised by a financial group, which focusses attention on the profits of the current year to practical exclusion of developing strength for the future. I see many examples of this, in which the organization has become so weakened by the time it sees its mistake that it has not the strength to embark on a different course, and therefore continues to become sicker and sicker. One species of this type of business anemia arises when the cost accountant becomes the master instead of the servant—applying cut-and-dried methods of evaluation, on a monthly or yearly basis without discrimination and without realizing the values which may reside in a research, a big idea or an active brain.

From these two examples, which I have purposely stated strongly, you may infer that I advocate the growing tendency to give technically trained men an increasing share in the management and policy-making activities of industry—and I do not mean to infer that financially trained men are not also essential.

A second obstacle is the cost, delay and uncertainty in the operation of our outmoded patent procedures. This is one of the major hindrances to the development of new industries and the supplying of new employment through the results of science. It is greatly to be hoped that favorable action will be taken by Congress on several recommendations by the Science Advisory Board aimed at increasing the presumptive validity of patents and the accuracy and ease of decisions by the courts.

A third obstacle is found in the increasing regulatory activities of the government for the stated objective of protecting the public, but sometimes in the nature of disastrous boomerangs. I believe that an increasing degree of regulation of business for protection of the public is a necessary accompaniment of increasing general complexity and competition. But this regulation should be benevolent and intelligent, two charac-

teristics which are not as prevalent as they should be. A fundamental difficulty appears to reside in the fact that in general we are governed by politicians rather than by statesmen. By this I mean that our elected rulers are generally men of alert perception to public opinion, nimble in debate, persuasive in oratory and skilful in dealing with group psychology; but these excellent qualities do not necessarily fit them to make wise decisions in such questions as: What technical procedure of subsidies, or curtailed planting, or research to create new industrial uses for his products, will best help the farmer and at the same time the country as a whole? or, Is a public utility company justified in charging on its bills to to-day's customers part of the cost of research designed to improve or cheapen the service of to-morrow's customers? These are profound questions, which greatly affect the ability of science to promote our social welfare. Our present method of deciding such questions is frequently expensive, illogical or ludicrous and is sometimes disastrous. However, while recognizing this difficulty, I can offer no solution to it and am unable to prove that we do not have the best of all possible types of governments in the best of all possible worlds, in the long run. Thus I will mention the government no more, except to point out that its present attitude toward both industry and science is in unflattering contrast with that of several European countries which have helped industry in a positive way by offering it definite incentives to embark upon a more active program of scientific and industrial research, considering this to be a national investment for future prosperity and employment.

Science in Educational Institutions

In educational institutions, science has no limitations in search for truth except those imposed by availability of ideas, workers, facilities and funds. Such institutions have always been the places where the great bulk of new discoveries are made and ideas born, and this will continue to be so, since there exist no other organizations where such studies can be similarly pursued. The practical aims of educational institutions in science are well described by Dr. Isaiah Bowman: "The trade school exists for the admirable purpose of putting practically trained men into jobs; the university exists, among other things, to create and expand the sciences that provide the jobs. It is in engineering that these two points of view are effectively joined."

The fact that the universities and engineering schools do feed industry with most of the new ideas, which industry then transforms into products of social value, was illustrated by Dr. Roger Adams in his recent presidential address before the American Chemical Society when he said, "The basic and fundamental information for over 95 per cent. of the industrial processes has been originally discovered and described by the university investigator." I recall a statement written by Herbert Hoover, when he was Secretary of Commerce, in which he expressed concern lest the industrial supremacy of America should be lost because our industrial leaders were not actively enough concerned with laying the foundations for the industrial future by strongly supporting pure scientific work at the present time. Mr. Hoover not only believed this, but he worked to bring about increased support of pure science by industry until the presidency brought him new and greater problems.

Growth of industry and employment and gain in civilization through science are like the growth of plants in nature: of many seeds which are scattered, only

a few grow to be vigorous plants; but if no seeds were produced and scattered there would be no plants at all. Scientific discoveries are the seeds of industry and public welfare, and the universities are the nurseries in which they are produced and nurtured to the point where some of them can be transplanted into the fields of industry. I once likened new industries to babies—they need shelter and nourishment, which they take in the form of patent protection and financing. But, before all, they need to be born, and their parents are science and invention. Neither laws nor committees nor juggling acts nor wishful thinking can perform the first necessary step of conception. To maintain and advance our civilization we need more and better scientific seeds and industrial babies. The educational institutions of higher learning are the birthplaces of this new knowledge, as well as the training and proving grounds for the young men and women who will carry this knowledge on and put it to practical use.

In discussing this matter with my friend, Dr. Charles F. Kettering, he expressed the opinion that one of the major problems of both industry and the universities is to facilitate this production and nurture of the seeds of industrial progress, in the universities, and to narrow the gap and hazard between discovery and successfully launched business. To do this requires closer cooperation between industry and educational institutions, involving more active research programs in the institutions, their more generous financial support by industry or by the captains of industry, and closer personal contacts between the men in the two groups who have related interests.

My own observations of what can be accomplished in an educational institution like the one which I represent convince me that there are really great opportunities along these lines. I have seen the sprouting of literally hundreds of promising ideas; I have seen the cooperative effort of professorial chemists, physicists, electrical engineers and metallurgists solve serious industrial problems that had baffled the skilled practical men of industry; I have seen a little of the desired financial support; and I have seen productive mutual stimulation in such cooperation. As I see it, a great university or engineering school already possesses, because of its teaching responsibilities, the principal overhead of staff, facilities and administrative organization necessary for a large research program, so that relatively large returns in the fields of research and development can be secured with relatively little additional financial support. It is in this direction that there lies, in my judgment, the greatest opportunity for increased contributions to public welfare through science in the leading educational institutions, and thus far the surface has only been scratched. I believe that, with more adequate financial support, a new order of institutional public service will be possible.

One peculiarity of scientific research is that its results can usually not be foreseen, for if they could be foretold they would not be new. Also, when a new discovery is made, it is not usually immediately obvious as to the possibilities of its practical uses. And again, the solution of a scientific problem may be a long, hard struggle—longer than was realized by a visitor who asked Harvard's President Conant what he was doing in his laboratory. When Conant replied, "We are seeking to discover the chemical formula for chlorophyl," his visitor exclaimed, "Why, how is that? You were working on that problem when I was here last year!"

Because of these uncertainties I can not predict just what the next big sci-

entific developments will be, but I can assure you that they will come and that they will be important. Among the fields that seem to me to show especial promise are: development of new industrial uses for farm products; improvements in transmission and utilization of electric power; great developments in materials and methods of building construction; increased range and precision of weather forecasting; conquest of hitherto unconquered diseases, both physical and mental; better regulation of bodily functions; a new era in biological discovery operating with the tools of physics, chemistry and engineering; a similar new era in physical science centered around atomic nuclear transformations; and so on, the field is literally limitless.

Having thus suggested a few of the more significant ways in which science may be made to contribute more effectively to the American program for social progress, through the agencies of government, industry and education, I close by saying that the greatest of all contributions of science is not to be found in the comforts, pleasures or profits which flow from it, but in the freedom and imagination which it has brought to the human spirit and the sense of relationship and unity in the world. Of all descriptions of the true spirit of science I like best the words of the ancient Greek philosopher, Aristotle, which appear engraved on the beautiful home of the National Academy of Sciences in Washington: "Search for truth is in one way hard and in another way easy, for it is evident that no one can master it fully nor miss it wholly, but each adds a little to our knowledge of Nature, and from all the facts assembled there arises a certain grandeur."

HEREDITY AND ENVIRONMENT IN THE LIGHT OF THE STUDY OF TWINS

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The question of the relative influence of heredity and environment is one of practical importance. If human abilities and personality are determined almost wholly by heredity, as some scientists maintain, the chief function of education and guidance is to determine what the individual's native characteristics are and then to plan his career in accordance with them. The individual's education and his choice of a vocation should, on this view, be very narrowly governed by his inborn capacity and his native interests. If these are disregarded he will be both unsuccessful and unhappy.

The question also bears on the possibility of altering the intelligence or behavior of human beings in the mass, and thereby improving the quality of human life. If the differences between persons are rigidly fixed, it follows that each person's ability and personality can not be modified by any environmental influence and that the general average must remain the same from one generation to another. On this view the only method of raising the general level of human intelligence or behavior is to improve the human stock through eugenics.

The view one holds on the question of heredity and environment is also bound up with one's general philosophy of life. It affects one's self-respect and self-esteem and the respect and esteem one has for others. It is involved in one's estimate of the people of various races, nations or social classes. We commonly characterize two generally contrasted attitudes on these matters as the aristocratic and the democratic points of view. The aristocratic philosophy is based on the assumption that one class of people inherit and pass on to their descendants superior traits, and that a sharp line divides the aristocrats from the common people. The democratic philosophy, while it may recognize the existence of individual differences, denies that the actual traits manifested by individuals are predominantly inherited or that social classes are distinguished chiefly by a wide difference in inherent characteristics.

It is natural that a question of such large practical importance should have been debated from time immemorial. It may seem strange, however, that the debate concerning heredity and environment has persisted so long without coming to a conclusion upon which scholars can agree. Ever since 1869, when Francis Galton published his "Hereditary Genius," scientists have been studying this question. In 1927 the National Society for the Study of Education published a yearbook in which were brought together a collection of studies by a large number of authors. The disagreement between these authors was more striking than their agreement. Similar disagreement is revealed in a more recent and complete review of the scientific literature on the problem by Gladys Schwesinger, entitled "Heredity and Environment."

There must be some reason why it is so difficult to come to a conclusion with which a large majority of scientists will agree. One reason will appear if one examines the typical studies. Nearly all the studies consist in a comparison of one group of persons with another. The army tests given during the World War

furnished an opportunity for a number of these comparisons on a large scale. For example, the average scores of the recruits from the various states of the Union were calculated and compared. The comparison of these average scores shows that they differed widely. The extremes were the states of Mississippi and Oregon, the men from the latter state making an average score just twice that of the men from the former. The averages of the men from the other states ranged between these extremes.

Oddly enough, these differences between the men in the various states have been seized upon by the hereditarians and the environmentalists alike as evidence in support of their own opinion. The hereditarians take these differences as evidence of variations in the native stock of the populations of the various states. The environmentalists, on the other hand, point out that these differences correspond to differences in the educational and cultural opportunities in the states as represented by the development of the school systems, the number of libraries, the circulation of magazines, and so on. The correspondence between the cultural opportunities and the intellectual level of the population can be demonstrated statistically. Which is cause and which is effect, however, may be the subject of interminable debate.

The same ambiguity renders inconclusive the comparison between races, between immigrants of various nationalities, between city dwellers and country dwellers, between members of various vocations and even between groups of persons who have had various amounts of education. That the person with longer schooling has higher ability might seem to be an unquestioned proof of the efficacy of education. The hereditarian, however, regards it as merely the result of the fact that only the person who is gifted by nature is capable of advancing to those levels of the school or college which demand higher intellectual capacity. Even the comparison between the ability of parents and children, with which Galton started the scientific investigation of this problem, gives us no means of discriminating between heredity and environment. Children, to be sure, have similar heredity to that of their parents, but they also have similar environment. Which factor, then, is more influential in producing the resultant similarity in character or ability is a matter of speculation.

To make any progress in answering the question some means must be found to separate the effect of heredity from that of environment. One method of doing this is to study foster children, particularly those who are separated from their parents in infancy. If foster children are adopted into a different grade of home from that of their true parents, and if their intelligence or behavior differs from what we would have expected if they had remained with their own parents, we may attribute the difference to a change in the environment. There is no space in this article to give an account of the results of the study of foster children. Suffice it to say that they give evidence that the children whose environment has been improved by adoption are themselves improved in both intelligence and conduct.

Still better subjects of study are furnished by twins. This was recognized by Galton himself, who made a rather extensive questionnaire investigation of the similarities between twins. Galton was the first one to bring out clearly the fact that there are two kinds of twins, the identical and the fraternal. Since Galton did not conduct tests or even interview his twins, however, he was not able to determine to any exact degree the amount of difference between the two types.

The reason that identical and fraternal

twins are such valuable subjects of study is that they enable us to make two entirely new comparisons. What these comparisons are we shall see in a moment. To understand them we must be clear about the nature of the difference between the two types of twins.

Fraternal twins are not fundamentally different from brothers and sisters in general. They may be either of the same sex or of opposite sexes, as in the case of brothers and sisters. This is because each twin develops from a separate ovum which happens to be fertilized at the same time as the other. The resemblance between fraternal twins is, then, on the average, as close and no closer than that between brothers and sisters, so far as their heredity is concerned. This means that, on the average, the heredity of fraternal twins is common to the extent of 50 per cent. Of course, in some pairs the common heredity is more than one half and in other pairs it is less than one half, but it averages just one half for all pairs taken together.

Identical twins, on the other hand, differ fundamentally from both fraternal twins and brothers and sisters. They are always of the same sex. We may know definitely, then, that if twins are of the opposite sex they are fraternal and not identical. Identical twins are of the same sex because they develop from one fertilized ovum which divides completely and forms two separate individuals. In some cases the division is not complete and then we have Siamese twins. Identical twins, then, have exactly the same heredity and are as much alike as are the two sides of the same person. Their hereditary resemblance is 100 per cent. instead of 50 per cent.

What now are the two comparisons that we can make, using these two types of twins? In the first place, we compare identical twins with fraternal twins who are brought up together. By this comparison we can discover whether the greater hereditary resemblance makes identical twins more alike in ability or in personality and, if so, how much more alike they are. Because identical and fraternal twins brought up together are alike in environment but different in heredity, this comparison enables us to separate the influence of environment and heredity and to measure the effect of a difference in heredity when environment remains the same. We thus avoid the ambiguity which inheres in nearly all the comparisons hitherto made by virtue of the fact that both environment and heredity differ, and that it is consequently impossible to determine how far the resultant difference is due to the one or the other factor.

What, then, in brief does this comparison show? It shows beyond question that differences in heredity do produce differences between people and that similarity produces resemblances. In the majority of physical and mental measurements which were applied to the two types of twins, identical twins are decidedly more alike than are fraternal twins. It may be objected that the environment of the two types of twins is not exactly similar. Identical twins, because of their greater similarity, may associate more constantly with each other, may have more largely the same friends, may dress alike, read the same books, attend the same lectures or movies and be treated alike by other people. Fraternal twins, on the other hand, may pursue somewhat more widely different paths. This may be granted, but it is probably a minor point which does not affect our general conclusion.

While it is true that identical twins are more alike than fraternal twins in the majority of traits, the contrast is greater in some traits than in others. This is an instructive fact. It suggests that some traits are determined more exclusively or more largely by heredity than are others.

The trait in which there is the greatest contrast between identical and fraternal twins is a physical trait, namely, the finger ridges which are recorded in finger prints. Identical twins have almost exactly the same number of finger ridges. In fact, the hand of one identical twin is as much alike in this respect to the hand of the other as are the two hands of the same person. The resemblance in the number of finger ridges of fraternal twins is very much less, being only about half as great as that of identical twins. This gives us a measure of the amount of contrast between the two types of twins in a trait which is not affected at all by the environment. It gives a base of comparison for the contrast in degree of resemblance in the other traits.

If we take the degree of contrast between the two types of twins as an indication of the influence of the hereditary factor we find that in no other traits that we have measured is the hereditary factor so great as in the case of finger ridges. In height the hereditary factor is fairly large, but in weight it is much less. Body weight, in other words, is influenced more by the environment than is height.

When we examine mental traits we find that they differ also in the degree to which they are determined by heredity. General mental ability, as measured by an intelligence test, seems to be determined to about the same degree as is weight. That is, it is determined partly by heredity and partly by environment, but how much by the two we can not judge accurately from this type of evidence. Educational achievement, as measured by a comprehensive achievement test, is determined somewhat more by the environment and somewhat less by heredity than is general intelligence.

In the case of traits of personality, such as emotional excitability or emotional balance and social adjustment or even rapidity of movement, the evidence is not quite clear. On the face of the returns it would appear that these traits of personality are determined much less by heredity than is mental ability or educational achievement. The tests in this field, however, are newer and such a conclusion should be entertained with a good deal of reservation. Further evidence on this point is yielded by the second comparison about to be described.

In the second comparison we use only the identical twins. In the first comparison two groups of twins were compared who have similar environment but different heredity. In the second comparison groups of twins are compared who have the same heredity but differ in environment.

In order to make this comparison it is necessary to find identical twins who have been separated in infancy and brought up under different surroundings. This is not easy. Twins, of course, are usually brought up together, and when they are brought up apart they may be so completely separated that they are out of touch with each other. Even if such pairs are found it is not always possible to persuade them to submit to an examination.

In a study recently completed at the University of Chicago[1] nineteen such pairs of separated identical twins were discovered and given a thoroughgoing examination. Only one such case had been reported in the literature previously. These nineteen pairs, because of the novelty of the evidence and of its conclusiveness, make a considerable contribution to our knowledge on the problem before us.

If we take the nineteen pairs as a whole and compare them with identical twins brought up together, we get a contrast which is somewhat analogous to that between identical twins and fraternal twins in the same home. We have here

[1] In collaboration with Drs. H. H. Newman and Karl J. Holzinger.

two groups similar in heredity but differing in environment. In all the mental traits which were tested the separated identical twins differ more than do the identical twins brought up together. The difference appears both in intelligence and educational achievement but is somewhat greater in the latter than in the former.

This comparison is not very satisfactory, however, because in some cases the separated twins were brought up in homes which were very much alike, were given about the same kind and amount of education and had lived subsequently under the same general conditions. It is more instructive, therefore, to examine the various separated pairs, to study the degrees of difference in their environment, and to examine the relation between the difference in their environment and the difference in their traits.

Two or three cases will illustrate the amount of difference in ability or personality which may be produced by a large difference in the environment. A rather specific difference in the environment which can be stated in fairly accurate terms is the difference in formal schooling. The largest difference in formal schooling of any of our pairs was found in the case of two sisters, one of whom had had only two years of schooling and the other of whom had gone through college, taken a teacher's course and subsequently became a high-school teacher as well as a teacher of music. The first sister had supplemented her formal schooling by her own efforts sufficiently so that she was able to hold a clerical position.

The difference in schooling, however, had produced a chasm which could not be bridged by self-education. If measured in terms of mental age the difference in ability of the two sisters is equivalent to a difference of four years in development. When expressed in terms of the intelligence quotient the difference is twenty-four points. The meaning of a difference of twenty-four points may be grasped from the fact that the lower score would put the individual in the lowest fifth of the whole population, and the higher score in the highest fifth. In other words, more than three fifths of the entire population would lie between these two scores. A few other pairs enjoyed widely different amounts of formal schooling, although in no other cases was the contrast so extreme as in this one. In one other pair the difference in IQ was nineteen and in a third it was seventeen.

It might be thought that these are isolated cases, and that the coincidence of a difference in education and in intellectual ability is an accident. That this is not true is shown by comparing the difference in education with the difference in intellectual ability throughout the entire group. In general, the two differences correspond very closely. If the difference in education is large the difference in ability is large, and if the difference in education is small the difference in ability is also small. As might be expected, the difference in educational achievement corresponds almost exactly to the difference in the amount of education which has been enjoyed. In other words, not only does a difference in education affect the ability of the individuals who are compared, but the amount of difference in education corresponds closely with the amount of difference in ability. Since inheritance is identical, this is conclusive evidence that education and training are large factors in ability.

What is the case with personality? We are not able to compare the difference in personality with the difference in environment with quite the same precision as in the case of ability. The reason is that degrees of difference in the environment do not correspond, so far as we can tell, to specific changes in personality in a given direction, so that we

can measure the parallelism between the two. We are compelled, then, to study individual cases to see whether the specific differences in personality which are found can reasonably be interpreted as corresponding to specific differences in the environment. Certain of the cases yield plausible evidence of such correspondence.

A pair of identical twin sisters were brought up under rather widely different environmental circumstances. The first was reared in a home of wealth and culture. The daughter enjoyed not only the regular advantages of the public school, but many additional educational advantages of an informal sort. Her foster father, who is a prominent professional man, has a well-stocked library which she was encouraged to make use of. A well-educated and highly cultured high-school teacher who is a near neighbor has taken the girl under her wing. She has received special musical education and has abundant opportunities for social life, in which she plays a leading and enthusiastic rôle.

The general home conditions and social surroundings of the twin sister offer a sharp contrast. Her foster father, who is now dead, occupied a humble position in life. Her foster mother is jealous of any intrusion upon their personal relations. She keeps her closely at home and withholds her so far as possible from the contacts of general social life. The home has meager cultural and educational advantages. While the girl has attended the same type of public high school as has her sister, and has taken some music lessons, her general cultural environment is quite mediocre, whereas that of her sister is exceptionally high.

The sisters exhibit marked contrast both in intellect and in personality. A noteworthy fact is that the favored sister is more superior on general intelligence tests than she is on tests of educational achievement. This is not surprising, since there is more contrast in the general intellectual environment than in formal schooling. In general manner the favored twin is poised, affable and self-confident, whereas her sister is somewhat awkward, diffident and restrained. In one of the tests the girls were asked to rate themselves in respect to certain contrasting traits of personality. The unfavored sister rated herself as having inferior intelligence and inferior character, whereas the favored sister rated herself as having a superior character and an average intelligence. The unfavored twin also rated herself as careless, inaccurate, forgetful and slow, whereas her sister rated herself as only somewhat careless, as accurate, as rather industrious, as having a rather good memory and being of average quickness. These ratings may not indicate that the sisters are actually as different as they report themselves to be. They do indicate, however, that one thinks much more highly of herself than the other, and this may explain the apparent self-confidence of the one and self-depreciation of the other.

In a pair of young men the contrast is not so much in temperament as it is in character. They impress the observer with the similarity of their appearance and manner. Both are silent and reticent and give the impression of possessing a great deal of reserve power. The graphic profiles of their scores on the Downey Will-Temperament Test, which is supposed to measure speed, aggressiveness and care and attention to detail, are very similar. However, one is a steady, industrious worker, has earned his living for a number of years, and carried successfully a good deal of responsibility in the management of a good-sized business enterprise. His brother has never held but one job, and that as a simple laborer for a short period of time. He has repeatedly run afoul of the law, and it is fairly safe to predict that he will never

hold a position of trust in the community. The conduct of these two men corresponds exactly with the standards of the homes in which they were brought up. In temperament they are the same, but in the choices that they make and in the social significance of their conduct they are as far apart as the east is from the west.

Two other examples show the effect of environment on personality. One consists of two sisters, one of whom was brought up on a farm and the other in a town. Although clearly identical in heredity, the one is now rugged, energetic, bold and rather mannish in manner, whereas the other is delicate, languorous and decidedly feminine in appearance and in behavior. Another pair of sisters, now in their teens, are very similar, except that one is emotionally very well balanced, while the other shows decided neurotic symptoms. The first has been brought up in a rather free and easy atmosphere, whereas the second has had an over-stimulating social life under the care of a neurotic foster mother. Incidentally, the latter girl is at least a year in advance of her sister in physiological maturity.

These examples are sufficient to show that sharp contrast may be produced in personality and character as well as in mental ability by differences in education, training and treatment. They give no warrant for the habit so many people have of attributing every trait of mind or of behavior which a person exhibits to inheritance from some ancestor who possessed a similar trait. The inheritance of such traits may take place, but there is no evidence that it must take place. On the contrary, there is good evidence that one's traits frequently have their origin in the environment as contrasted with heredity.

The study of twins has not answered all the questions that we would like to have answered. It does not inform us whether heredity or environment is the more influential. It has not yet indicated just what the limits of the influence of environment are. It does indicate that the environment may affect all kinds of traits; intellectual, temperamental and social. It indicates that this influence is large enough to be of the greatest importance, and that human nature may be improved or debased to a degree which many have thought impossible. It probably indicates that we are far from having exhausted the possibilities of education and training for the enlargement of mental power and the improvement of behavior. It indicates that large returns may be expected from a continued attempt to improve the methods of education. Finally, it indicates that while democracy may need to be adapted to the differences between people, it is not the idle dream which some extreme hereditarians have made it out to be.

THE PRESENT STATUS OF COSMOLOGY. II

By Professor RICHARD C. TOLMAN
THE CALIFORNIA INSTITUTE OF TECHNOLOGY

THE EXTRA-GALACTIC NEBULAE

And now we come to the last stage of cosmology that we can treat, the study of the nebulae, those great objects of which our own galaxy is a sample, that lie scattered far beyond with no decrease in distribution for the four hundred million light years that we can now explore. This is a stage of cosmological inquiry so vast and pregnant that we can only undertake it in awe and humbleness of spirit.

Just as I have prefaced the treatment of earlier stages by a map or diagram, so we can commence the present study with a map that gives the results of Hubble's counts of the numbers of nebulae in different directions out as far as the twentieth magnitude. Our map, Fig. 23, is now one of the whole sky unrolled on to a flat surface. Each dot or circle on the map gives a place where the number of nebulae per unit area has been determined. The small black dots which predominate indicate places where the count is about what it is on the average, large black dots indicate excess counts, open circles places where the count was low, and crosses have been added where the count was exceedingly low or high (only one of the latter, since thick clusters were avoided). The little minus signs indicate places where no nebulae at all were found. These lie along the equator of our own galaxy in a great irregular belt of obscuration, undoubtedly due to the clouds of obscuring dust in our own system. You will have noticed that the numbers of nebulae in different directions are not so far from uniform, and when corrected in a reasonable manner by Hubble for the effect of an absorbing layer of dust, the large scale uniformity of distribution is somewhat improved.

Next I must show you some actual photographs of these nebulae, originally so named because their images often present a hazy or nebulous appearance. The forms in which nebulae occur may be divided into three main classes. There is a small group of nebulae which are quite irregular in shape, a larger

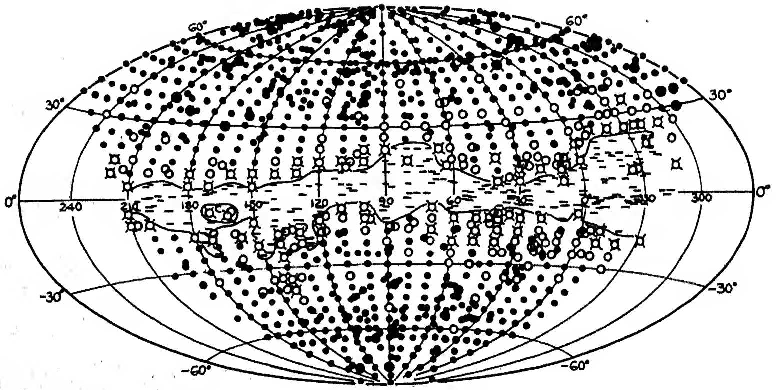
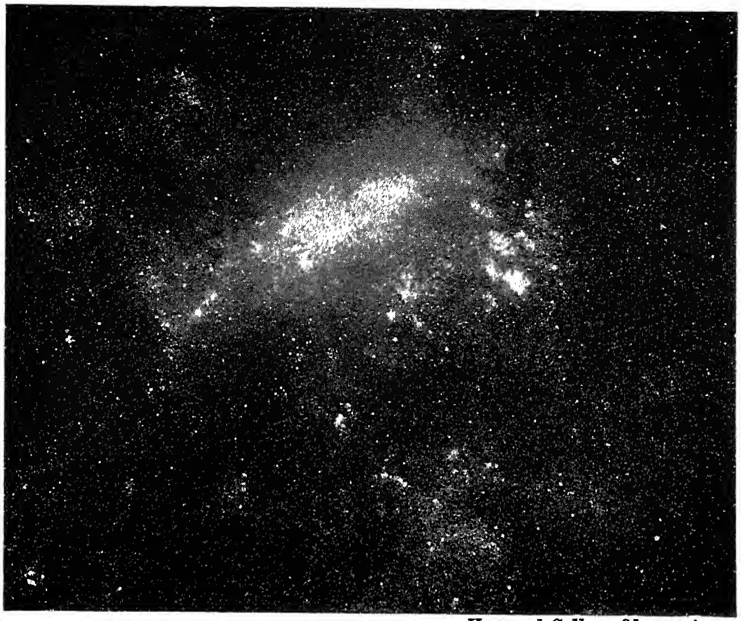
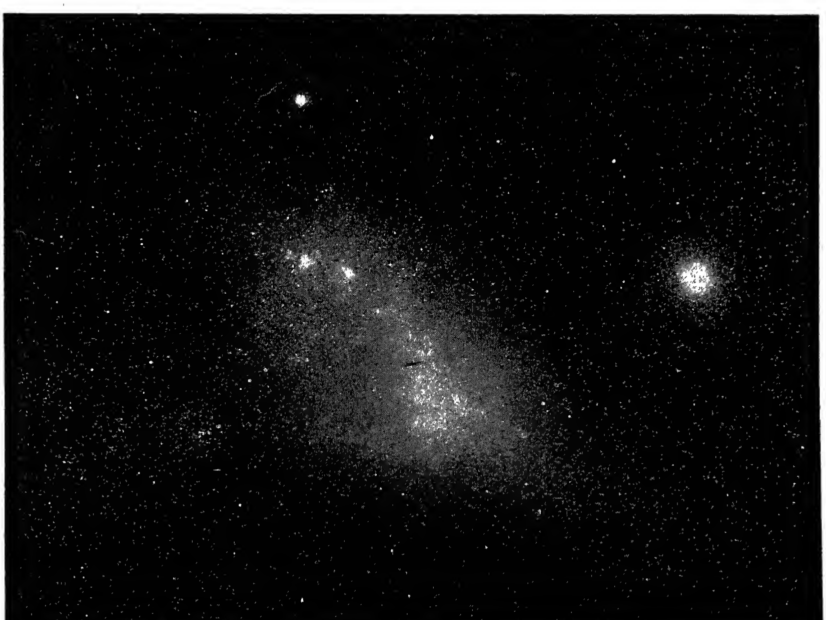


FIG. 23. NEBULAR COUNTS OUT TO THE 20TH MAGNITUDE.
HUBBLE, MT. WILSON CONTR. NO. 485, PUBLISHED IN *Astrophys. Jour.*, 79: 8, 1934. FOR DESCRIPTION SEE TEXT.



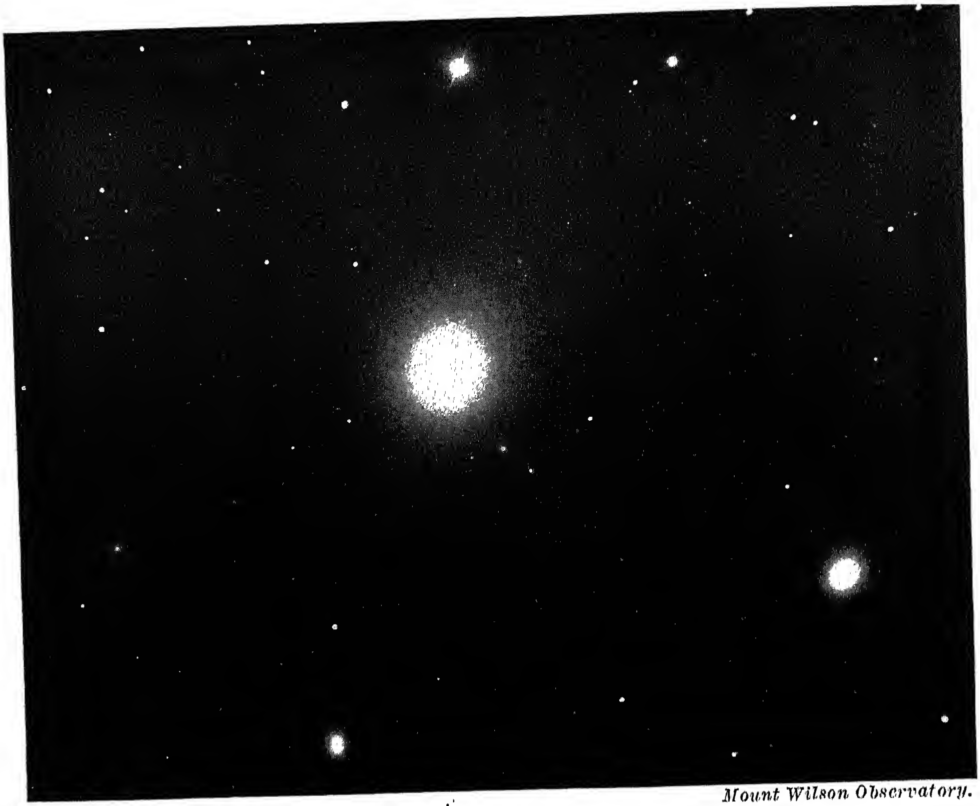
Harvard College Observatory.

FIG. 24. THE LARGER MAGELLANIC CLOUD.



Harvard College Observatory.

FIG. 25. THE SMALLER MAGELLANIC CLOUD.



Mount Wilson Observatory.

FIG. 26. SPHERICAL NEBULA IN VIRGO CLUSTER

group which are ellipsoidal varying from globular to lenticular form, and finally the most numerous group with a more or less pronounced spiral structure.

The nearest nebulae of all to our own galaxy are the two Magellanic Clouds, easily visible to the naked eye in the Southern Hemisphere. They belong to the group of irregular nebulae, and are near enough so that on the same scale as that of Plaskett's diagram of the galaxy (Fig. 14) they would have appeared not very far below the lower left-hand corner of the figure. They are also near enough so that individual stars of different types can be easily recognized within them, a matter of importance in the study of their structure and distance. Fig. 24 gives the larger and nearer of the two Magellanic Clouds, and Fig. 25 gives the more distant lesser cloud together with a globular cluster that happens to lie in the same direction.

Now for some elliptical nebulae. First, Fig. 26, much further away than the Magellanic Clouds, is a spherical nebula in the Virgo cluster of nebulae, together with some smaller nebulae and stars; next, Fig. 27, a slightly less spherical one, Messier 32; and then, Figs. 28 and 29, two even more flattened forms, N.G.C. 5866 and 3115.

Finally, we must have some spiral nebulae which are among the most beautiful objects in the heavens. First, Fig. 30, a late type spiral, Messier 33, taken with a long exposure to show that the spiral structure goes well into the interior; second, Fig. 31, an earlier type spiral, Messier 81, exposed so as to show

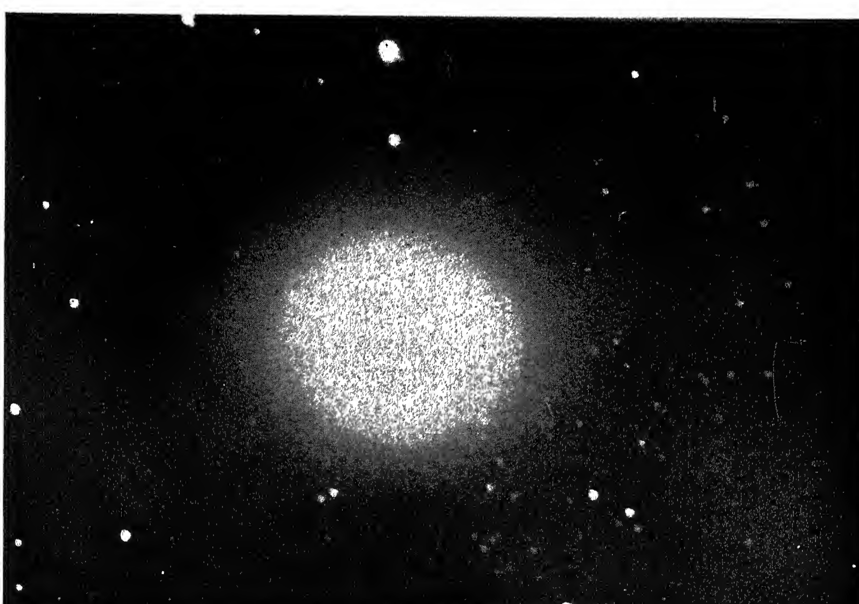
clearly the external spiral arms; then, Fig. 32, a very early type, N.G.C. 4594, nearly on edge, which shows very well the bright central nucleus and layer of absorbing dust; and last, Fig. 33, another spiral, N.G.C. 4565, precisely on edge. It took two nights with a total of five hours' careful exposure on the Mount Wilson 60-inch reflector to get this last fine picture, and as you see it has almost exactly the same appearance as Plaskett's diagram of our own galaxy.

Several further photographs will be of interest to complete our general pictures of nebulae. Fig. 34 gives a small portion of a distant cluster of nebulae in Corona Borealis, with many nebulae on the same plate; Fig. 35 gives some elliptical and spiral nebulae on the same plate in the constellation Leo; and Fig. 36 gives two views of the spiral nebula N.G.C. 4273 in the Virgo cluster, showing at the right as of February 16, 1936, the enormous new star—a super nova—which has temporarily blazed up in that nebula.

Internal Structure of the Nebulae

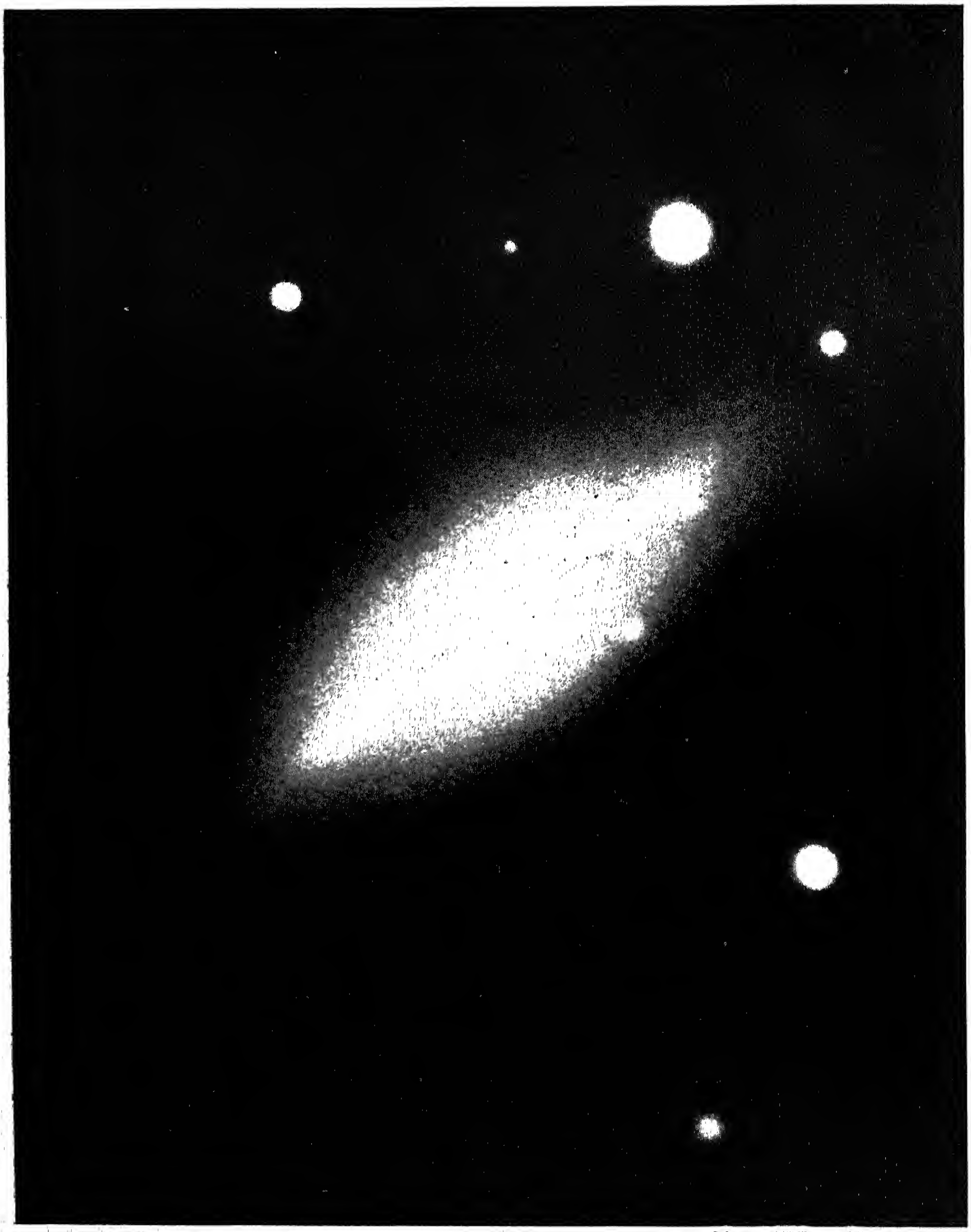
We are now ready to consider the internal structure and behavior of nebulae a little more in detail. For such studies we need nearby objects and shall be specially interested in spiral nebulae, since the "average" nebula may be taken as approximating a so-called Sb spiral. Hence we are very fortunate to find in the Andromeda constellation a beautiful spiral, Messier 31, which is near enough and large enough so that it can actually be seen with the naked eye as a small hazy patch about $\frac{1}{2}°$ in diameter.

Fig. 37 is a photograph showing Messier 31 together with two smaller companions, N.G.C. 205 and 221. This nebula is of special interest to astronomers, since the investigations of Stebbins and of Hubble make us believe it to be of about the same size and detailed structure as our own galaxy. Fig. 38 shows on the left star clouds in Sagittarius which belong to our own galaxy, and on the right taken with the 100-inch



Mount Wilson Observatory.

FIG. 27. SLIGHTLY ELLIPTICAL NEBULA, MESSIER 32.



Mount Wilson Observatory.

FIG. 28. ELLIPTICAL NEBULA, N.G.C. 5866.

telescope what we believe to be similar star clouds in the Andromeda Nebula. Fig. 39 gives a portion of the Andromeda Nebula with objects which Hubble identifies as a star cloud, an open cluster of stars, a globular cluster, and a Cepheid variable star. These Cepheid variables are specially important for checking estimates of distance with the help of Shapley's calibration. It has also been possible to identify irregular variable stars, P Cygni stars, helium stars of classes O and B_0, and novae in a number of the nearer extragalactic nebulae.

In addition to the use of direct photography, it is also important to employ the spectroscope in studying the internal structure and behavior of nebulae. Fig. 41 gives a photograph of the spectrum produced by light from the central nucleus of the Andromeda Nebula, placed between comparison spectra to assist in identifying the structure. It has a recognizable structure, which shows that the material which emitted the light was similar to that in the surface of our own sun, in spite of the fact that we have not yet been able to resolve the nucleus into separate stars. The spectroscope has also made it possible to study the action of gravity inside of nebulae, since differences in velocity of approach or recession—due to rotation of nebular material around the center—will produce different shifts in the positions of spectral lines. As a rough summary of our present knowledge of internal structure and behavior, we can say that all evidence now points to the same kinds of material, and to the same laws of physics and chemistry inside the nebulae as in our own galaxy.

External Distribution and Motions of Nebulae

Last, and most important of all for cosmology, we must consider the external distribution and motions of all the nebulae as far out as observations can be made. Thereby, we can hope to approach some adequate view of the largest possible sample of the whole universe that our present telescopes will reach.

As already seen from the map given in Fig. 23, the distribution of nebulae in *different directions* appears roughly uniform. The counts for that map were taken way out to the twentieth magnitude and in such a manner as to avoid thick clusters of nebulae which occur in some places. The uniformity appears much less when counts are taken to lesser distances and in such a way as to include clusters. Thus, as emphasized by Shapley, out to the thirteenth magnitude there are twice as many nebulae in the northern as in the southern hemisphere. This, however, can be regarded as largely due to the populous Virgo cluster in our own neighborhood in the northern hemisphere. Hence, since only a small fraction of all the nebulae occur in large clusters, we can regard the rough uniformity in different directions as well established.

By making counts out to different magnitudes, it is also possible to obtain an idea as to the distribution of nebulae not only in different directions but to *different distances* as well. Here too we find a rough uniformity, with the nebulae scattered on the average about a million light years apart. And this uniformity continues—at least in first approximation—way out to the four hundred million (400,000,000) light years that the 100-inch telescope has been able to penetrate. I like to think that this awe-inspiring sameness may perhaps break down, when we have finished our construction of the 200-inch telescope at the California Institute of Technology.

Finally, we must consider the motions of this great system of nebulae. Here we can again call upon the spectroscope to help us, since—by the so-called Doppler effect—light from an approach-

ing nebula would have its spectrum shifted towards the violet and light from a receding nebula towards the red. This is similar to the shift in pitch of the sound from a locomotive whistle—towards the treble when the locomotive is approaching and towards the bass when receding.

Our first information as to nebular motions was given by the pioneer work of Slipher of the Lowell Observatory, who showed that nearly all the nearby nebulae were apparently receding from us. This was followed in 1929 by a preliminary study of Hubble, which showed that the apparent velocity of recession was greater the more distant the nebula, the red-shift increasing approximately as the distance; and this was followed in succeeding years by the extended observations of Hubble and Humason, which have now shown a close proportionality between velocity of recession and distance out to more than one hundred million (100,000,000) light years.

The illustration on page 39, Fig. 40, is a very instructive one prepared by Hubble and Humason to make the method clear by which the velocity-distance relation was obtained. The method of de-

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FIG. 29. LENTICULAR NEBULA, N.G.C. 3115.

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FIG. 30. LATE TYPE SPIRAL, MESSIER 33.

Mount Wilson Observatory.

FIG. 31. SPIRAL NEBULA, MESSIER 81.

termining distances is illustrated at the right and the method of determining velocities of recession at the left.

To get a good determination of distance, it is best to take a cluster of closely associated nebulae, all of which will be approximately at the same distance from us, and then measure the average magnitude of the nebulae in the cluster. These cluster nebulae are mostly elliptical, instead of being spirals like the average isolated nebulae, and at the right-hand side of the present slide you will see the decreasing photographic images of such nebulae as we go to more and more distant clusters.

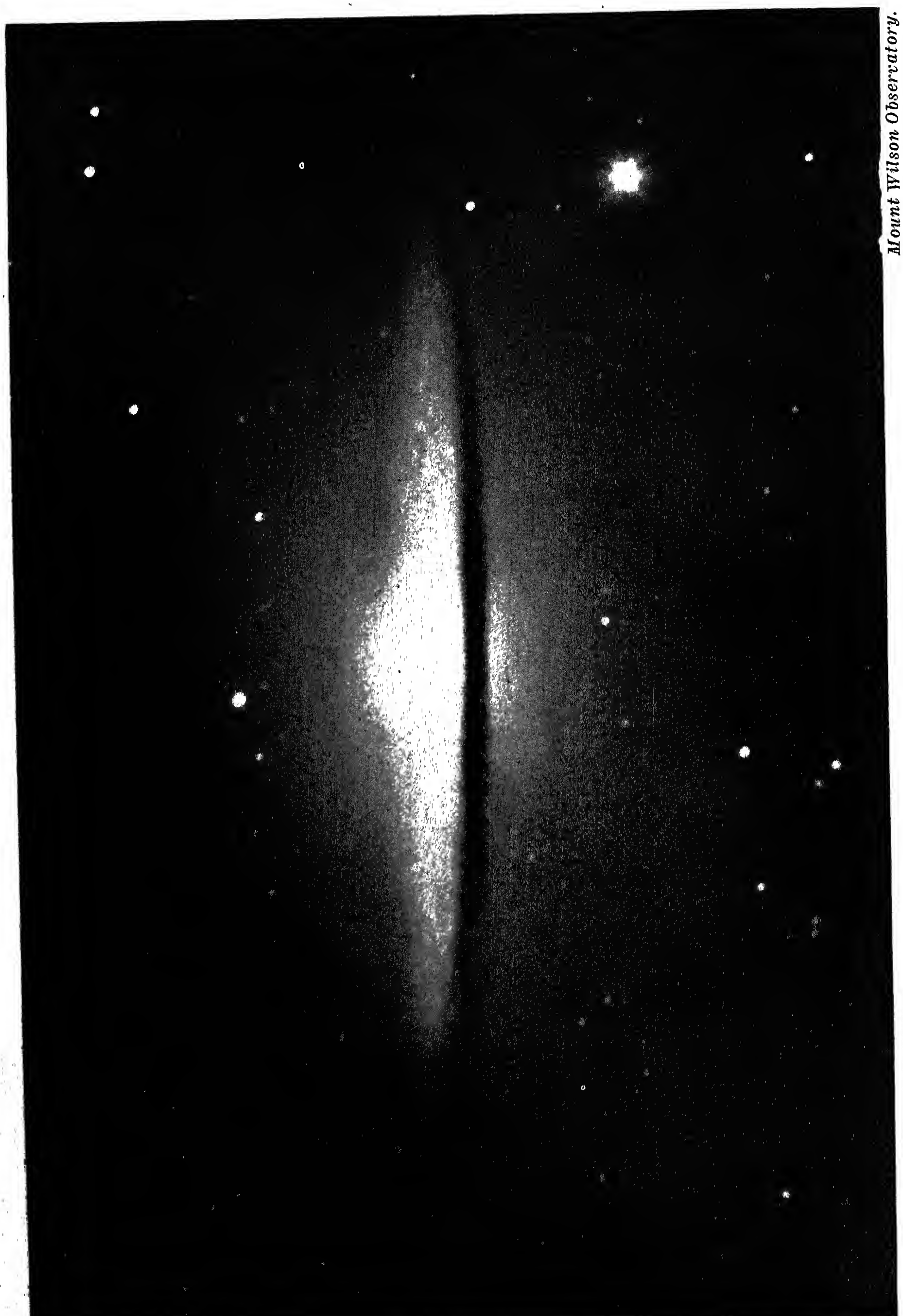
Having in this way determined the distances to different clusters, we may then determine the velocities of recession by measuring the red-shift in the spectra of these cluster nebulae. This is shown at the left of the present slide, where you will see the spectra that correspond to the direct photographs of nebulae shown at the right. Each nebular spectrum is placed between two comparison spectra with an arrow pointing to the H and K absorption lines for calcium. This makes it easy to measure the increasing shift towards the red—that is towards the right in the present photograph—in the position of these absorption lines. In this way we are led to the conclusion that the nebulae are receding with a velocity which increases proportionally to their distance, up to the enormous speed of 14,300 miles a second for the most distant nebula given in the figure.

It is important to realize that this recession between the nebulae is a mutual affair. If *we* see a nebula receding from *us,* an observer on that nebula would see *our* galaxy receding from *him.* Once more we must guard against the anthropocentric fallacy of thinking of ourselves as too important. There is no unique center for the recession, since an observer on *any* nebula would find—just as *we* do—that all the other nebulae were receding from him, faster and faster the further the distance. It is like the motion of spots painted on an endless strip of elastic rubber, each portion of which is being stretched at the same rate. Taking any spot on the elastic strip as the standpoint of reference, the spots on both sides will be receding therefrom, faster and faster the greater their distance.

We are thus led to our temporarily final large-scale picture of the material universe around us. In accordance with our best present views, it may be called an expanding universe since the principal objects in it are all in mutual recession. It is a universe of enormous size, since the part already observed stretches out to the four hundred million light years where objects can still be photographed with long exposure on the 100-inch telescope. It is a universe filled with a roughly uniform distribution of nebulae, one for each cube of space a million light years along an edge. And out of the hundred million such nebulae, which lie within the range of our largest telescope, our galaxy with its thirty thousand million stars is only one single sample.

Theoretical Treatment of Cosmology

To conclude my description of the present status of cosmology, I must be allowed to say a few words about the theoretical methods that are to be used in treating the phenomena of nebular distribution and motion, since this is the field where my own connection with cosmology has been. Without doubt in my own mind, the methods that must be employed in the study of cosmology at the present time are those provided by the principles of gravitational behavior which have resulted from Einstein's general theory of relativity. This has for me a very special interest because of my personal friendship with Einstein, and

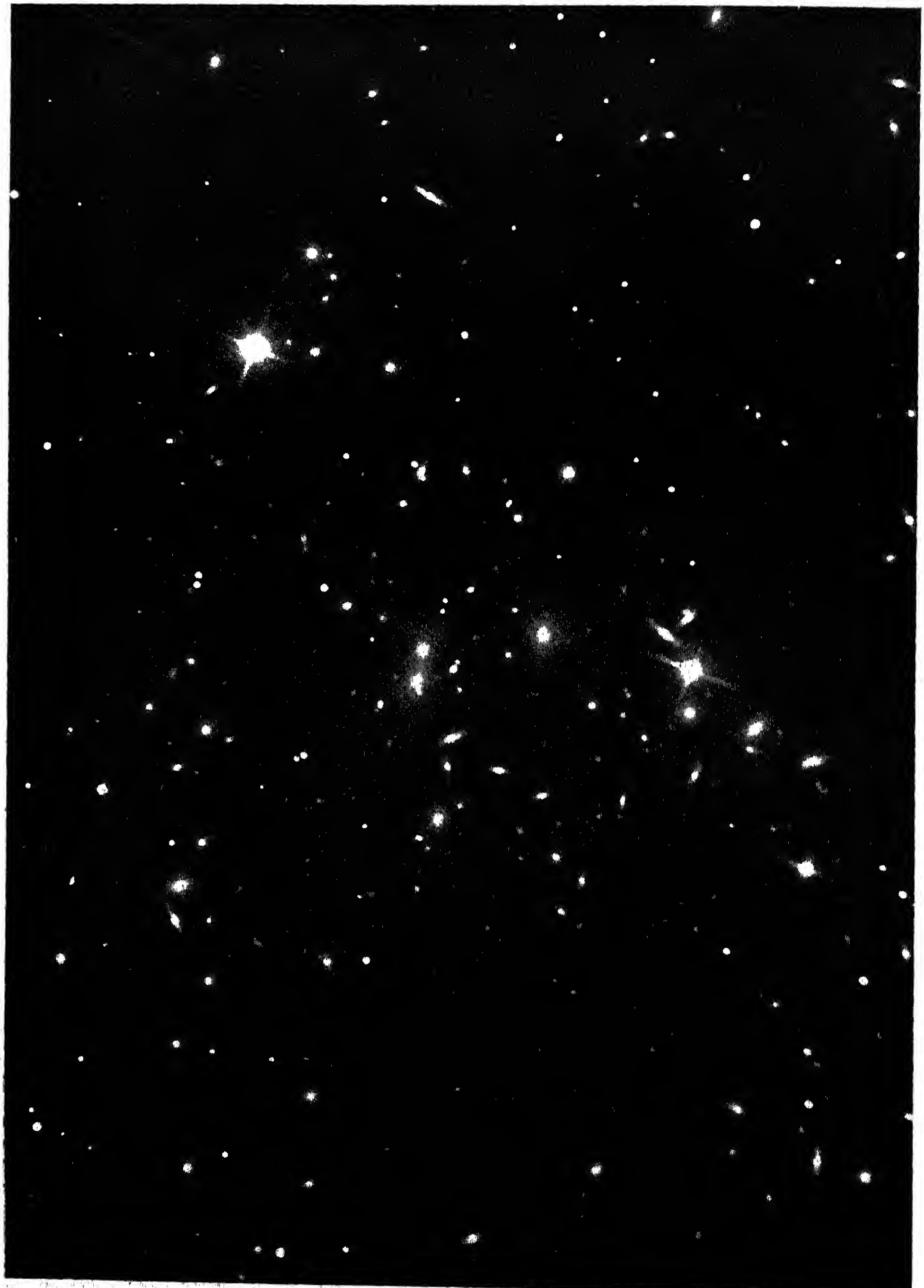


Mount Wilson Observatory.

FIG. 32. VERY EARLY TYPE SPIRAL, N.G.C. 4594.

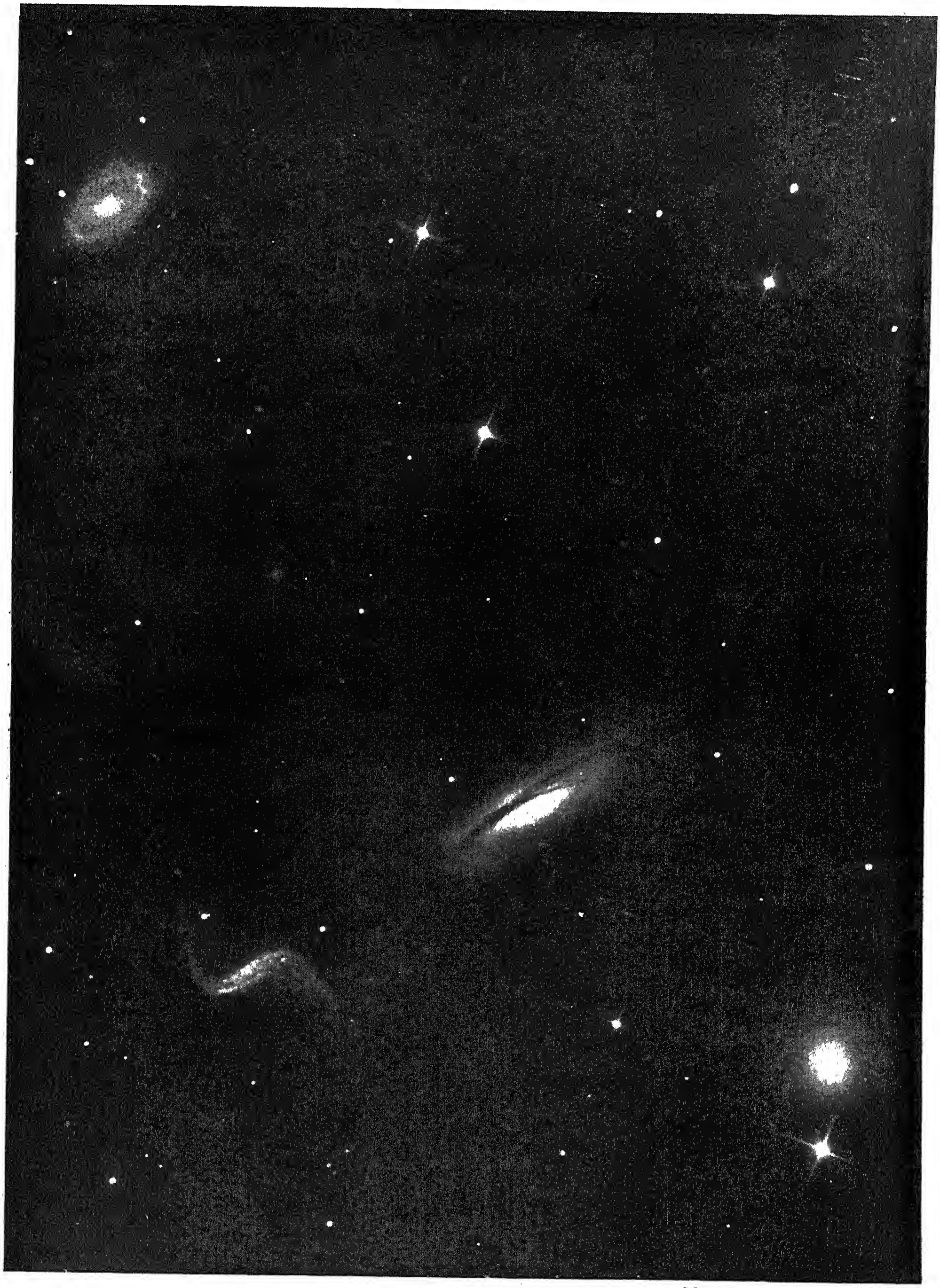
Mount Wilson Observatory.

FIG. 33. SPIRAL NEBULA ON EDGE, N.G.C. 4565.



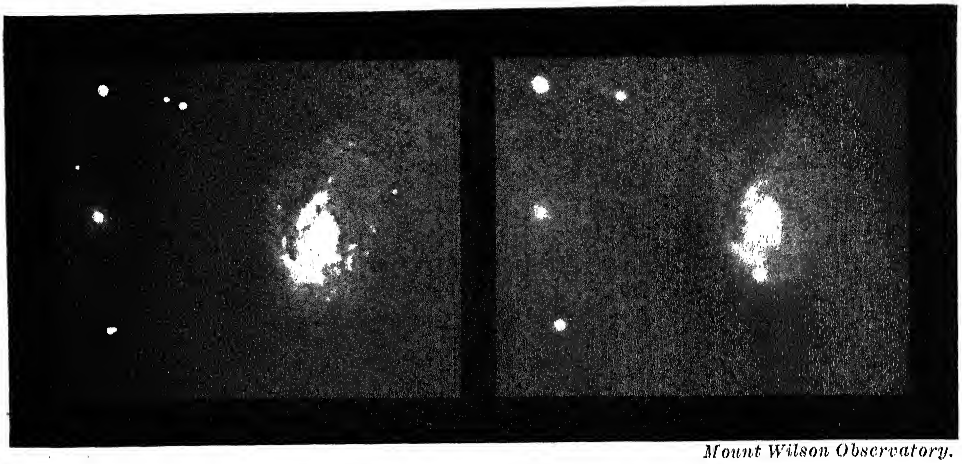
Mount Wilson Observatory.

FIG. 34. SMALL PORTION OF CLUSTER OF NEBULAE IN CORONA BOREALIS.



Mount Wilson Observatory.

FIG. 35. NEBULAE IN THE CONSTELLATION LEO.



Mount Wilson Observatory.

FIG. 36. SPIRAL NEBULA, N.G.C. 4273, SHOWING SUPER NOVA AT RIGHT.

with Americans such as Kennedy and Robertson, who have made important experimental or theoretical contributions to relativity.

Although the relativistic theory of gravitation undoubtedly provides the theoretical methods that must be employed at the present time in studying the distribution and motions of the nebulae, it would not be wise to assert that these methods will necessarily prove sufficient for the solution of the problems of cosmology. The theory of relativity, together with the quantum mechanics, are the two greatest advances in physical science since the time of Newton. Nevertheless, just as Newton's theory of gravitation is now included as a first approximation in Einstein's theory, so we must believe that the theory of relativity will sometime be itself included in a wider point of view.

So far, however, attempts to treat the problems of nebular behavior except by the relativistic theory of gravitation have not added much to our comprehension. On the one hand, Professor Milne, of Oxford, has strongly advocated the treatment of nebular recession as a kinematic problem by methods which do not introduce the dynamical features of the relativistic theory of gravitation. Nevertheless, as might perhaps be expected, and as has been shown in detail by the penetrating analysis of Robertson,[2] this merely leads to a treatment which agrees with that of relativity except for the greater flexibility but decreased predictive power that result from the omission of dynamics. On the other hand, my colleague, Professor Zwicky, has been one of those who have urged the explanation of the nebular red-shift as due to some effect of distance or time of passage which does not involve recessional motion, and I think we must be very open-minded as to such possibilities. Nevertheless, no satisfactory detailed mechanism, other than recession, has yet been presented to explain the red-shift, and—as Dr. Hubble and I have put it—we both incline to the opinion[3] "that if the red-shift is not due to recessional motion, its explanation will probably involve some quite new physical principles."

As to the measure of success which has been achieved by applying the methods of relativity to the distribution and motions of the nebulae, I can not give a detailed statement, since this would be

[2] Robertson, *Astrophys. Jour.*, 82: 284, 1935.

[3] Hubble and Tolman, *Astrophys. Jour.*, 82: 302, 1935.

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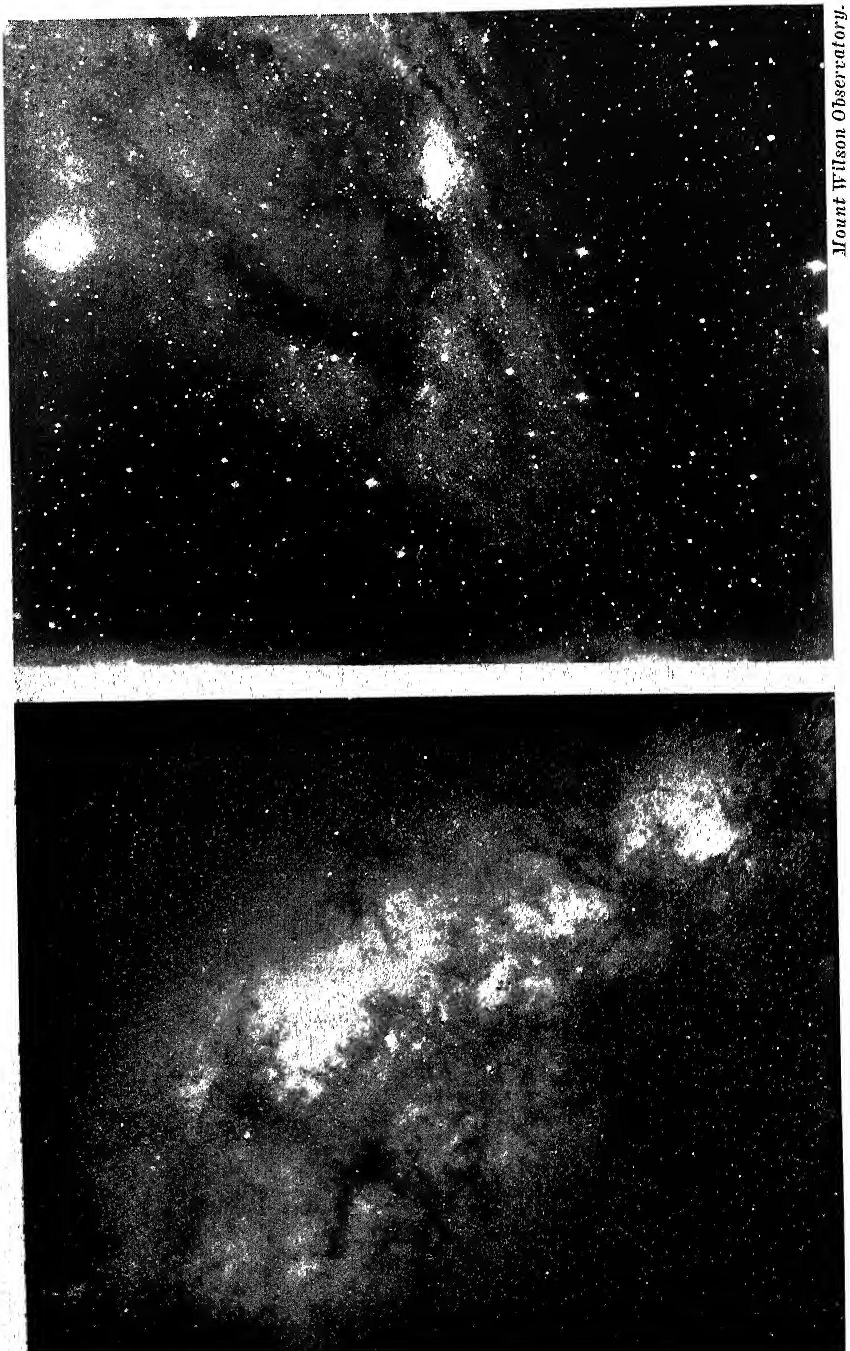
FIG. 37. THE GREAT SPIRAL NEBULA IN ANDROMEDA.



Mount Wilson Observatory.

FIG. 38. AT LEFT STAR CLOUDS IN SAGITTARIUS

BELONGING TO OUR OWN SYSTEM, TAKEN WITH A SMALL CAMERA; AT RIGHT STAR CLOUDS IN THE ANDROMEDA NEBULA, TAKEN WITH THE 100-INCH REFLECTOR.

too long and too technical. In a general way it can be said that the methods are applied by constructing conceptual mathematical models of the universe, which agree on the one hand with the principles of relativistic mechanics, and agree on the other hand with as many observational facts in the actual universe as possible. The extent of the correspondence between theory and reality which has thus been achieved is not unsatisfactory.

I will only mention three features of these conceptual models, one very satisfactory feature, one puzzling feature and one attractive but rather dangerous feature.

The particular satisfactory feature which I have in mind is the finding that the relativistic theory of gravitation would not permit any stable stationary distribution of nebulae. A uniform distribution of nebulae must in any case either be expanding or contracting, and hence by the principle of minimum hypothesis it seems wise to try to explain the nebular red-shift as due to expansion.

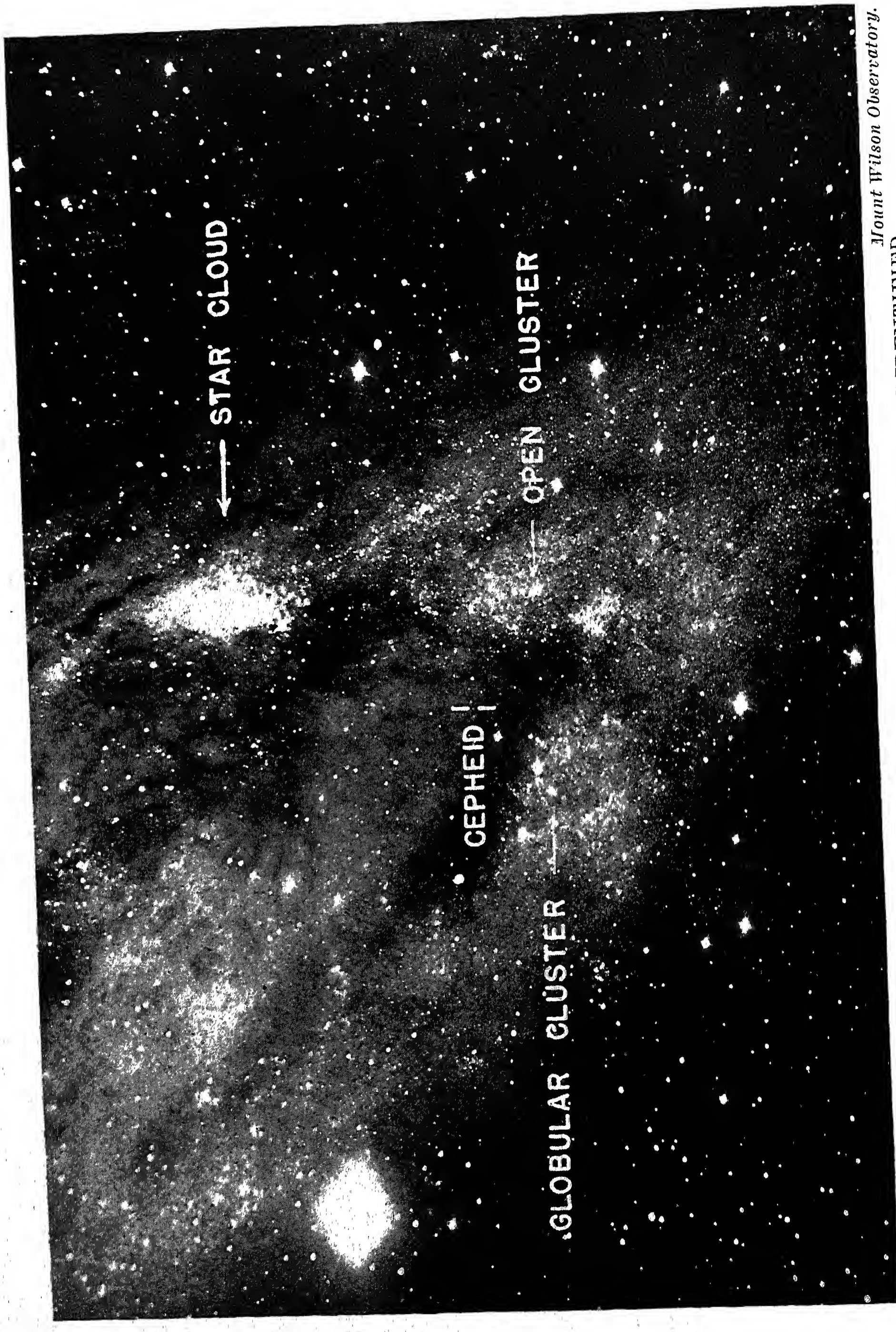
The puzzling feature of the models results from the finding of Dr. Hubble and myself[3] that the numbers of nebulae actually observed at great distances could not be accounted for on the basis of a homogeneous expanding model, without introducing an unexpectedly large amount of gravitational curvature. This curvature appears to be greater in amount than that which would be produced by the masses of the nebulae themselves. Nevertheless, since our computations were first made, the work of Sinclair Smith[4] has led to a considerable increase in the best estimates of nebular masses, and in addition there is always the possibility of *inter-nebular* material which will contribute to gravitational curvature.

The attractive but dangerous feature of our conceptual models lies in the possibility of their use for extrapolating from our actual observations of the universe to greater distances and to earlier and later times. There are great dangers, however, in carrying such extrapolations over more than a modest interval.

These dangers may be illustrated by the story of the German scientists in the city of Berlin who planned a scientific expedition to the North Pole. As a preliminary it was decided to send out a survey party to investigate the possibilities of obtaining supplies on the route north. After a short time, this party returned with the report that they had proceeded north from the city of Berlin and had decided that there would be no difficulty in obtaining the essential supplies, since—making due allowance for statistical fluctuations—it could be concluded by a process of extrapolation that for each quarter of a kilometer on the route north there would be found at least one inn with attached beer garden.

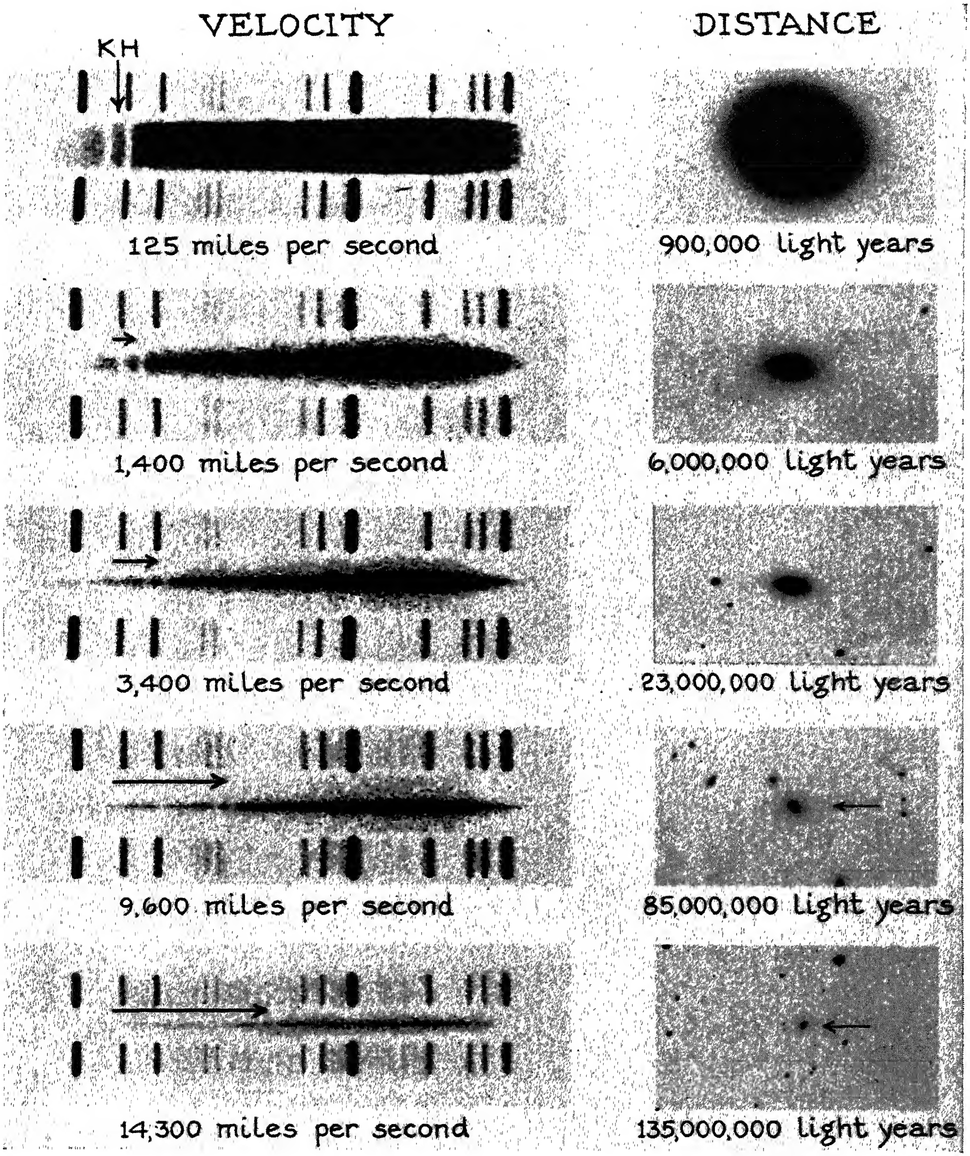
In the case of cosmology, the difficulties of drawing conclusions by extrapolation, as to the properties of the universe at distances beyond our present observations and as to the past and future history of the universe, are greatly increased by the wide variety of quite different mathematically satisfactory models which can still agree with the limited data now available. Thus we can have closed models of finite volume and open ones of infinite volume; we can have models which expand to zero density never to return and those which undergo a continued succession of expansions and contractions; and we can have homogeneous models which are alike in all their parts and heterogeneous models which would show quite different properties at sufficient distances. Trying to take an open-minded and optimistic view, I have myself a predilection for models of infinite volume which are not completely

[4] Smith, *Astrophys. Jour.*, 83: 23, 1936.



Mount Wilson Observatory.

FIG. 39. PORTION OF ANDROMEDA NEBULA WITH OBJECTS IDENTIFIED BY HUBBLE.



Mount Wilson Observatory.

FIG. 40. METHOD OF DETERMINING VELOCITY–DISTANCE RELATION FOR EXTRA-GALACTIC NEBULAE.

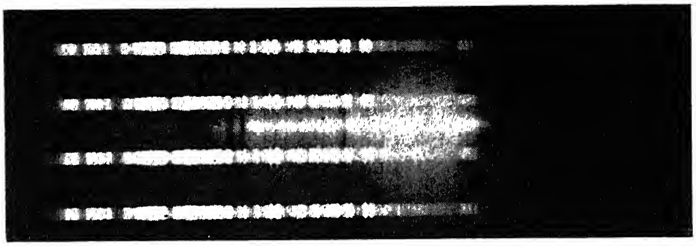
Spectra and direct photographs were prepared by Hubble and Humason at the Mount Wilson Observatory. In order of increasing distance the nebulae are first a nearby one, N.G.C. 221, followed by members of the Virgo, Pisces, Ursa Major and Gemini Clusters.

closed, for models which would not expand into nothingness never to return, and for models which could show quite different properties at sufficient distances. But other scientists have other predilections, and the *facts* for the actual universe are not yet available. Our two hundred inch telescope should help us to get some of them.

On account of these difficulties and dangers, I should like to conclude this description of the present status of cosmology, by emphasizing—in words that I have used once before[5]—

the special necessity in the field of cosmology of avoiding the evils of autistic or wish-fulfilling thinking. In the first place, the problems of cosmology are necessarily extensive and intricate and must be attacked in the light of very meager information. Hence we must be careful not to substitute the comfortable certainties of some simple mathematical model in place of the great complexities of the actual universe. In the second place, it is evident that the past history of the universe and the future fate of man are involved in the issue of our studies. Hence we must be specially careful to keep our judgments uninfected by the demands of theology and unswerved by human hopes and fears. . . .

It is appropriate to approach the problems of cosmology with feelings of respect for their importance, of awe for their vastness, and of exultation for the temerity of the human mind in attempting to solve them. They must be treated, however, by the detailed, critical and dispassionate methods of the scientist.



Mount Wilson Observatory.

FIG. 41. SPECTRUM OF CENTRAL NUCLEUS OF ANDROMEDA NEBULA.

[5] "Relativity, Thermodynamics and Cosmology," Oxford, 1934.

LOUIS JOBLOT AND THE PROTOZOA

By Dr. LORANDE LOSS WOODRUFF
PROFESSOR OF PROTOZOOLOGY, YALE UNIVERSITY

TOWARD the end of the seventeenth century, while Leeuwenhoek was affording the first glimpses of the "world of the infinitely little" in a series of letters to the Royal Society of London, Louis Joblot of Paris began observations which culminated in 1718 in the publication of the first separate treatise on microscopic organisms. Moreover, since most of the animals which Joblot described and named are Protozoa, he is the author of the pioneer volume in the field of protozoology.

Studies of the available data in regard to the life of Joblot, other than may be gleaned from his book, afford but a meager picture of the man. We know that he was born at Bar-le-Duc (Meuse) in 1645, the fourth child of Nicholas and Ann Joblot. At the age of thirty-five he became assistant professor of mathematics, geometry and perspective at the Royal Academy of Painting and Sculpture in Paris, and nineteen years later succeeded to the professorship. He retired as emeritus professor in 1721, and died in April, 1723, just four months before Leeuwenhoek.

In addition to his professorial duties, which he apparently conducted with high success, Joblot's interest ranged in the fields of magnetism, optics and the construction of microscopes; the latter probably affording the stimulus, or at least the opportunity, to make his long-continued observations in microbiology that alone entitle him to be remembered to-day.

Joblot's book on microscopes and what he saw with them is a remarkable and curious production. Not only is it the first separate treatise devoted to "animalcules" in general and the Protozoa in particular, but since nearly all the observations recorded are original, it had no real successor in the field. Indeed, when the microscope and its revelations attracted considerable popular interest during the middle of the century, Joblot's book was reissued to compete with various works, largely compilations, such as Baker's "The Microscope Made Easy" (1742) and "Employments for the Microscope" (1753), and Adams' "Micrographia Illustrata" (1746), each of which ran through several editions.[1] Unfortunately, the new publishers of Joblot's treatise saw fit to insert data from notes left by him, including material taken bodily from other authors, apparently in an attempt to widen its scope—and sale. However, nothing was added to the descriptions of the Protozoa.

The new edition (1754–55) hardly enhanced Joblot's reputation because the rarity of the limited original edition, published at the expense of the author, rendered it little known, and so his observations were frequently judged without reference to the progress of microscopy that had taken place since 1718. In fact, over a century later we find that Dujardin, in his great work on the Infusoria, cites Joblot's observations as following shortly after those of John Hill, published in 1752.[2] We shall consider only the original edition of 1718, which is now exceedingly rare; one of the few copies known to have survived being in the library of the writer. (Fig. 1–3.)

Joblot's book essentially comprises two treatises bound together. The first consists of 78 pages and 22 plates devoted to the improved microscopes that he employed, while the second comprises 96 pages and 12 plates assigned to his new

[1] Woodruff, SCIENTIFIC MONTHLY, Vol. 7, 1918.
[2] Woodruff, *American Naturalist*, Vol. 60, 1926.

DESCRIPTIONS
ET USAGES
DE PLUSIEURS NOUVEAUX
MICROSCOPES,
TANT SIMPLES QUE COMPOSEZ;

Avec de nouvelles obſervations faites ſur une multitude innombrable d'inſectes, & d'autres animaux de diverſes eſpeces, qui naiſſent dans des liqueurs preparees, & dans celles qui ne le ſont point.

Par L. JOBLOT, *Profeſſeur Royal en Mathématiques; de l'Académie Royale de Peinture & Sculpture; demeurant ſur le Quay de l'Horloge du Palais, au gros Raiſin.*

A PARIS,

Chez JACQUES COLLOMBAT Imprimeur ordinaire du Roy, & de l'Académie Royale de Peinture & Sculpture; ruë Saint Jacques, au Pelican.

M. DCC. XVIII.

AVEC APPROBATIONS ET PRIVILEGE DU ROY.

FIG. 1

observations made with the instruments. It is perhaps significant of the author's real interest that both of the "parts" of his book are entitled "Nouvelles Observations," and merely the general title page emphasizes "Microscopes." Certainly, the present-day importance of the book lies in what Joblot observed and not in the various simple and compound microscopes that he devised and constructed with the aid of a professional instrument maker of Paris. (Fig. 4.)

Surveying the thirty-five chapters devoted to observations, one is impressed not so much with the range—which is wide—as by the point of view from which some of the observations are made. It may well be that when Joblot began his work in 1680 he was merely trying to verify the reports that must have reached him of Leeuwenhoek's discoveries, though, strange to say, the latter's name is not mentioned once in regard to observations on the Infusoria. At all events, Joblot's curiosity was not easily satisfied, for during nearly forty years as opportunity offered he continued his avocation. No wonder he described many "animalcules" new to science. However, the chief interest of his work is not the organisms which he discovered in the long series of infusions that he studied, but his endeavor to give them appropriate names and to discover their origin.

Joblot's informal effort to supply names for the animals that he found is of some significance, because it is the first general attempt in the field of microbiological nomenclature. He sought some real or fanciful resemblance between his tiny "insects" and "fishes" and various objects and well-known animals. Thus he described the "swan," the "kidney," "the silver bagpipe," "the glutton," "the bird crown," "the weaver's shuttle," etc. Sometimes he applied the same name to different organisms. Indeed, Adams's comment that the "resemblances, I apprehend, in some cases arose from the lively imagination and hasty determination of Mr. Joblot," is only too true; but it was made a half century after Joblot's time, when Adams was incorporating verbatim much of Joblot's text as well as many of his figures in a later edition of the "Micrographia Illustrata." Joblot's discovery of the contractile vacuole must atone for the complex eyes, etc., with which he endowed some species.

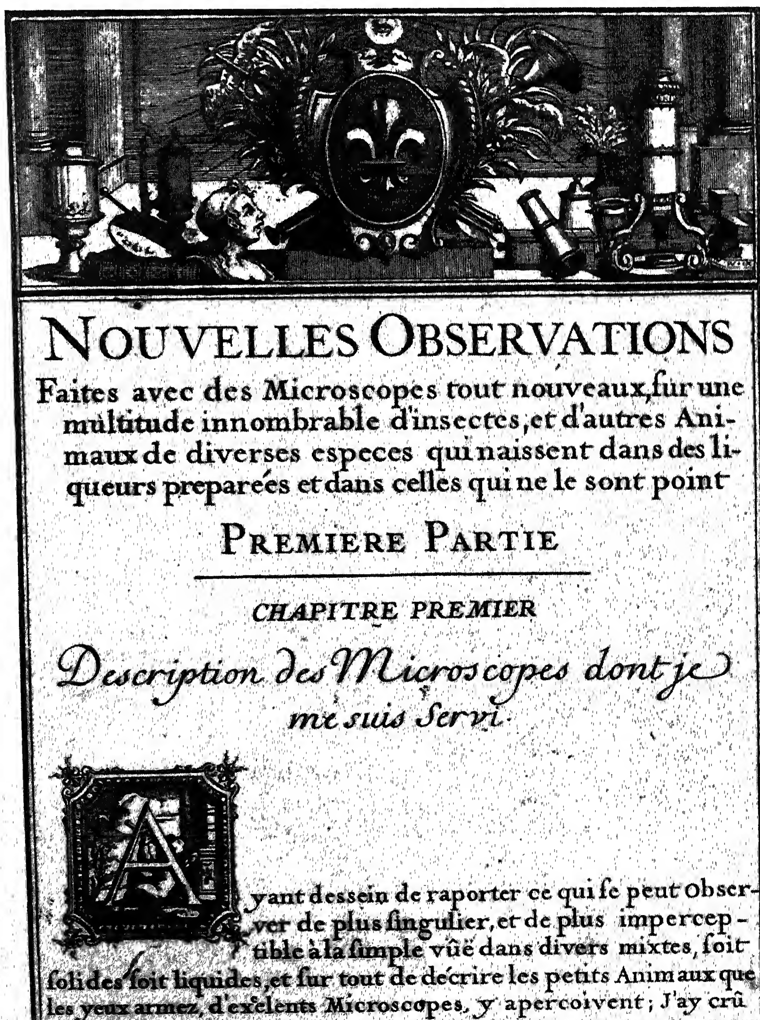
Most of the appellations supplied by Joblot have, of course, long since been forgotten, but Paramecium is still the "slipper" (chausson) animalcule. And it is interesting to note that the accompanying illustration is probably the first satisfactorily identifiable figure of Paramecium ever published, although, as Dujardin remarked with some justice, Joblot might well have used his own slipper as his model instead of the animals that he found in an infusion of oak bark which he studied at various times throughout a year. (Fig. 5, A-B-C.) It may be recalled that Hill in 1752 coined the name Paramecium for certain animals figured in part by an anonymous contributor to the *Philosophical Transactions* in 1703.

The organisms that Joblot discovered in his infusions of pinks, roses, marigolds, tree bark, tea, mushrooms, and so on, would naturally lead him to consider their origin. It appears that on one occasion, in particular, he was amazed to note the teeming population of a hay infusion which had been standing for only a few days. So he proceeded to investigate and it is his experiments in this field that deserve especial emphasis.

Joblot took some new hay, divided it between two vessels and added cold water to each. Then he sealed one vessel with a piece of vellum and left the other open to the air. Within two days he discovered several kinds of animals in about equal numbers in each infusion, and accordingly he concluded that the animals

in the infusions arose from "eggs" present on the hay before the experiment was started.

So far Joblot's results were not new, but then he attempted to determine if "eggs" were present in the air. He took some of the same kind of hay, boiled it in water for more than a quarter of an hour and then put equal parts of the infusion into two similar vessels. One vessel he sealed while the contents were still warm and the other he left open to the air. Then he studied these infusions day by day and found many organisms in the open vessel but none at all in the sealed one. Obviously, boiling had killed any "eggs" that were present on the hay, but it had not made the infusion unfit to support life. Thereupon Joblot proceeded to remove the cover from the sealed vessel and allow air access to its contents; and then he found that animals appeared in it as they had in the previously unsealed vessel. Accordingly, he was led to conclude that the animals present in both vessels had been



NOUVELLES OBSERVATIONS

Faites avec des Microscopes tout nouveaux, sur une multitude innombrable d'insectes, et d'autres Animaux de diverses especes qui naissent dans des liqueurs preparées et dans celles qui ne le sont point

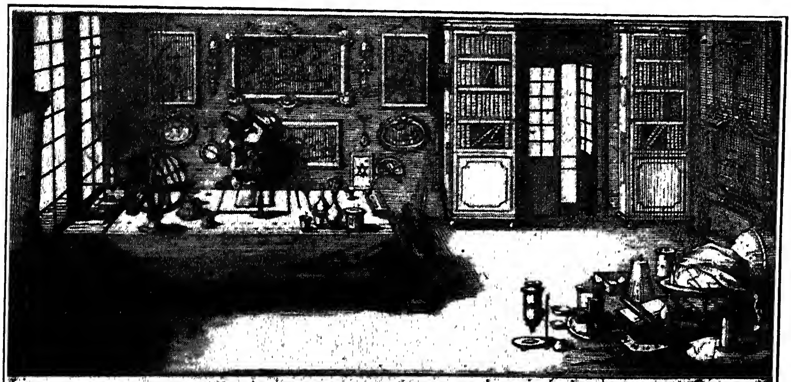
PREMIERE PARTIE

CHAPITRE PREMIER

Description des Microscopes dont je me suis Servi.

Ayant dessein de raporter ce qui se peut observer de plus singulier, et de plus imperceptible à la simple vûë dans divers mixtes, soit solides soit liquides, et sur tout de décrire les petits Animaux que les yeux armez d'exelents Microscopes, y apercoivent; J'ay crû

Fig. 2



NOUVELLES

OBSERVATIONS,

Faites avec de nouveaux Microſcopes, ſur une multitude innombrable d'inſectes, & d'autres animaux de diverſes eſpeces, qui naiſſent dans des liqueurs préparées, & dans celles qui ne le ſont point.

SECONDE PARTIE.

AVERTISSEMENT.

APRE'S avoir expliqué dans la premiere Partie de cet Ouvrage, la conſtruction, & quelques uſages de pluſieurs nouveaux Microſcopes à liqueurs, beaucoup plus parfaits & plus commodes qu'aucun de ceux qui ſont venus juſqu'à preſent à ma connoiſſance; il eſt neceſſaire de les mettre en uſage, pour faire l'Hiſtoire anatomique d'une multitude

a

FIG. 3

derived from "eggs" floating in the air, since boiling had destroyed any that might have been present on the hay.

It is unfortunate that Joblot failed to give more details of these and other experiments that he began in October, 1711, but it appears evident that they were neatly and effectively executed and that he was justified in regarding the series as adequate to prove that neither "alteration, nor corruption, nor a foul odor is the cause of the generation of these animals." The air, he said, teems with microscopic organisms, some of which settle on appropriate plants and live and multiply, while others drop their eggs directly in the air. In either event the source of the life in infusions is the

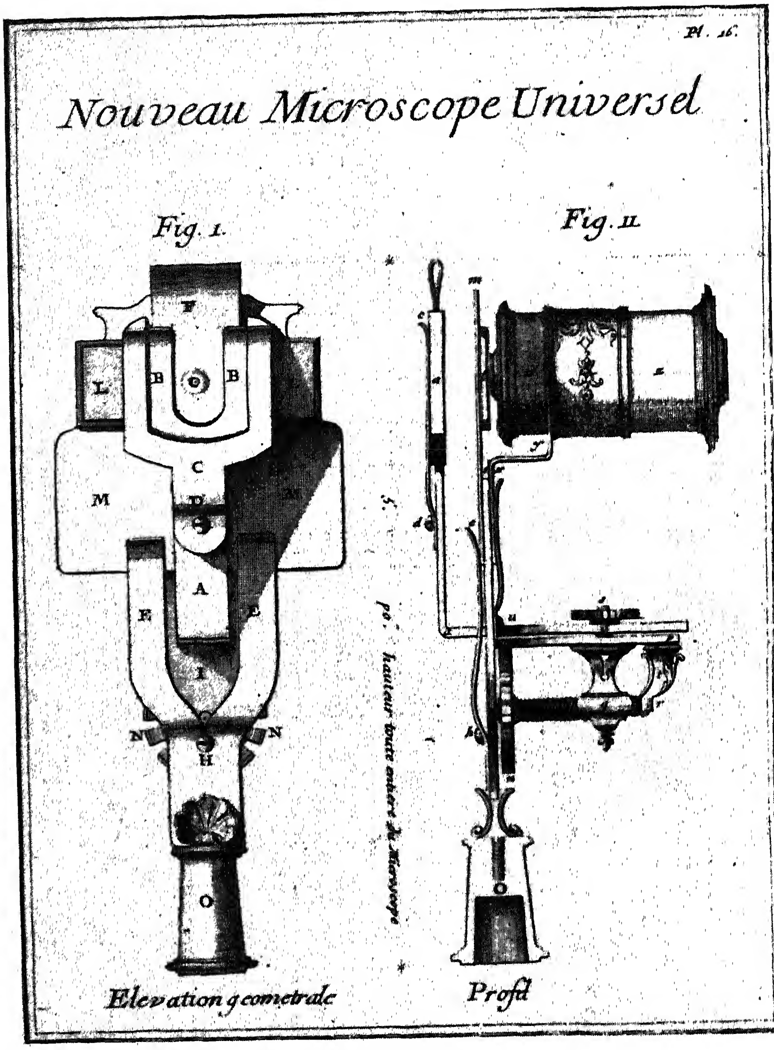


FIG. 4

atmosphere. Spontaneous generation is not only inconceivable, but contrary to reason and religion.

Ostensibly Joblot formulated his views solely on the basis of his own interesting experiments, and well he might, but, as has been emphasized by Dobell, it seems hardly possible that he was ignorant of similar ideas advanced earlier by Leeuwenhoek, Harris and others.[3] But even after due allowance is made for any unacknowledged indebtedness to other students, there still remains more than sufficient original work to warrant regarding him as an important pioneer in the long series of students of spontaneous generation.

Joblot apparently was the first to demonstrate not only that organisms do not appear in an infusion that has been boiled and sealed from atmospheric contamination, but also that such boiled infusions, though devoid of life, again readily support life when it is admitted

[3] C. Dobell, *Parasitology*, Vol. 15, 1923.

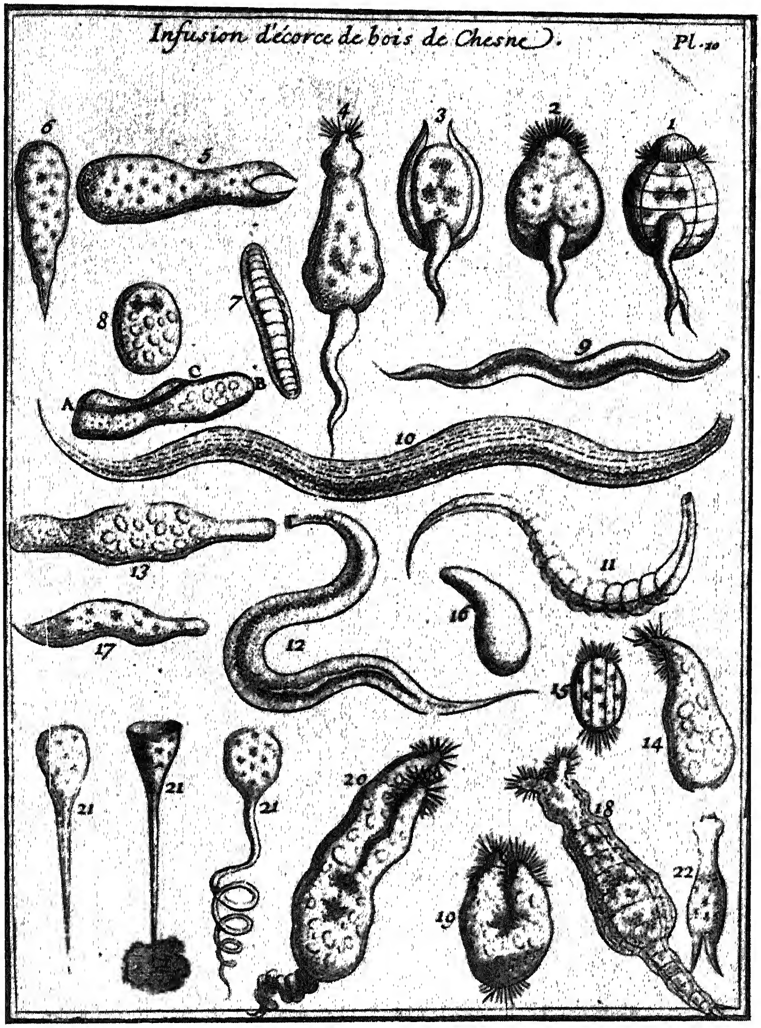


FIG. 5

from the air. These conclusions in themselves are of great importance, and especially so when it appears that he was the first to employ heat as a method of eliminating life in such investigations—a method exploited by Needham, Spallanzani and others nearly half a century later. Certainly his contributions deserve more recognition than has usually been accorded them in surveys of the doctrine of biogenesis and the history of protozoology.

BRAIN WAVES

By Dr. R. W. GERARD
PROFESSOR OF PHYSIOLOGY, UNIVERSITY OF CHICAGO

Let the reader picture himself sitting comfortably before the fireplace listening to one of Beethoven's immortal symphonies coming over the radio. At the intermission you might turn down the dial and sit bemused, thinking about the music, rather than simply sensing it. Should you happen to wonder about its beauty, your thoughts would have strayed into questions of the philosophy of music, or, if you happen to speculate on Beethoven's genius, mirrored in the composition, you might be said to be considering its psychology. If, however, your interest turns to the problem of how the music was produced and how it came to you, you are essentially considering its physiology.

Suppose you had no evidence as to how the music was produced—if you had never seen or heard of an orchestra—it would be extremely difficult to deduce, only from the loud-speaker outpourings, anything of its essential character: the instruments, the players, the leader. Yet, in a very real sense, that is the problem which faces investigators in an attempt to unravel the physiology of the brain, for they have had to be satisfied with study by television and teleaudition. True, not so much by wireless as by ordinary wired telegraphy, for the sense organs on and below the surface of the body that receive stimuli and send them on to the nervous system are connected to it by means of long threadlike extensions of nerve cells which carry messages along them, and similarly the cells in the central nervous system send their long processes out to muscle fibers and so control their activity. But aside from that slight difference, we have had to study the functions of the brain by finding out what happens elsewhere in the animal. For example, sense organs have been stimulated and the consequent movements observed; the work of the brain could then be inferred.

The classical methods used in studying the nature of brain activity have been far from fruitless—quite the contrary. The method of introspection, for example, and its modern variations, as Gestalt psychology, and the more objective introspection by proxy of psycho-analysis, on the one hand, and behaviorist and conditioned reflex studies on the other, have contributed very valuable information. But, for most of this work, it would be quite immaterial in obtaining and interpreting the results, whether the cranial cavity were filled with a sponge or with a brain, since this separate organ rarely entered into the picture. Whether or not the brain had been known, the same experiments could have been made and the same observations would have resulted.

Some physiologists have attacked this problem differently and, in the last decade, made extraordinarily good use of one important property of the message which travels along nerve fibers. When a nerve fiber is stimulated, either directly or through a sense organ attached to it, there is set up in this fiber some kind of an impulse or message which travels along quite rapidly and produces an effect at the other end. Almost a century ago the exciting discovery was made that an electrical change is associated with this message as it travels along. This so-called action potential could be used as an index or measure of the passage of nerve impulses in nerves—massive bundles of nerve fibers containing, often, several thousand of them side by side. Each fiber acts like a tiny battery

producing several thousandths of a volt, and when all or many are active together the potentials were quite readily measurable by the instruments available. These have been much refined during the last ten years and from two sides the experiments have been pushed definitely closer to the central nervous system itself.

On the sensory side, for example, it has been possible to study the impulses coming from a single sense organ along a single fiber and to examine the way in which they are modified by changes in the stimulus to that sense organ. The classical work of Adrian showed, for example, that if the strength of the stimulus is increased the individual message is not modified, but rather an increasing number of them are sent, each following more closely its predecessor. Instead of half a dozen impulses within a second with a weak touch, a strong one may discharge many hundred in a couple of seconds. This was an important advance, and gives a better basis for relating conscious sensation to the neural happenings in the brain. On the motor side, likewise, Sherrington analyzed muscle contractions produced by various reflex stimuli and showed that a small one differs from a larger one in two respects. In a strong contraction, the nerve cell in the spinal cord, like the strongly stimulated sense cell, sends a greater number of impulses and at a faster rate along its fiber to the muscle, and in addition more nerve cells join in the discharge, so that more muscle cells contract and each does so more vigorously. Such studies really bring us into the central nervous system, since the cells whose fibers extend down the motor nerves to muscles and whose messages make them contract are part of this organ. Still, the brain itself remained essentially that large unknown territory into which sensory messages debouched and from which motor impulses emerged.

One would have expected to be able to follow these electrical changes on through the paths in the central nervous system, and to a very slight extent indeed, this was successfully done. The difficulty has been that, when small numbers of fibers carrying these electrical changes are imbedded in large numbers of inactive fibers or cells, or, when the potentials are appearing in individual fibers at different times or in scattered directions, the tiny batteries are so short circuited or so oppose one another that the final voltage was too small to study with the instruments available.

Still other methods have been applied successfully in unraveling neural function. It is not merely a scientific dogma that conscious activity is intimately related to the brain, although some physicists seem to doubt this. It has been shown that when light is thrown into the eyes a particular portion of the brain increases its chemical activity, receives more blood and becomes warmer. When the brain is depressed by anesthetics, consciousness is diminished in parallel fashion; when its activity is increased by stimulant drugs, consciousness is enhanced; and other drugs having unique actions on the brain invoke also unique conscious experiences—as the visual hallucinations of mescal or hashish. Further evidence comes from human disease and experimental destructions in animals. Injuries to particular regions of the nervous system lead to particular losses of sensation, of motor power, of concepts, or learning ability or of memory. If a nerve from receptor organs is cut, sensation is abolished. When motor nerves are cut, paralysis ensues. When parts of the cerebrum are missing, the effects range from paralysis through over-emotionalism to complete idiocy. Small injuries will produce characteristic defects of one or another kind, depending on the part of the nervous system involved. Clearly, not only is consciousness related to the brain, but in

some detail certain anatomical regions are concerned with particular psychic processes.

Yet I return to the earlier statement that primarily we have studied the brain and its work by distant observation. The most direct evidence of its action was introspection; a subject says, "I do—or do not—feel this stimulus." Otherwise the experimenter depended on the contraction of a muscle or secretion of a gland to discover the processes that have occurred in the central nervous system.

This situation has altered with acceleration during the last decade or so, as a direct result of the improvement of our tools, mainly the development of the amplifier. Rapid oscillographs have also been important, but, if small electric changes can be amplified as desired, often several million times, a quick instrument to record them is not a great problem. Actually, delicacy and accuracy of measurement have increased so that potentials of a millionth of a volt are now studied, as were previously those of a thousandth; and many anticipate such revolutionary advances in physiology from the application of electrical magnification as occurred in anatomy with increased optical magnification.

It is now possible to follow potentials of one or two up to several hundred millionths of a volt within the central nervous system, and results have, to a certain extent, confirmed expectations. For example, it is possible, by directing the electrode, with which these potentials are being obtained, into known anatomical parts of the brain, to tell when and under what conditions of stimulation these regions are thrown into activity. With it in pathways supposed to belong to the optic or the tactile system, the anatomy can be simply and rapidly checked physiologically by flashing light in the eye or touching a paw; for potentials do appear in the expected locations in the brain. Extensive work along those lines is being carried out, some of which may be rapidly summarized.

In the cat's brain, it has proved possible to trace optic impulses throughout all the anatomically accepted structures, through the optic nerves and tracts into the midbrain, thalamus, appropriate parts of the radiations and on to the cerebral cortex. It has even been possible to settle by electrical study some disagreement, between several kinds of anatomical evidence, as to the location of some optic regions. Similar stories could be told about many senses. When a watch or metronome is allowed to tick near a cat's ear, potentials led from any part of the auditory pathways or from the auditory cortex will reproduce the sound in a loud speaker; even songs can be recognized. Pressure and muscle sense have been followed through the brain stem and cerebrum, in their proper regions. It is rather surprising that, in an animal rather deeply under an anesthetic, one may stimulate a single hair on the foot and obtain an electrical record of the passage of nerve impulses all the way into the brain. The anesthetic does not work by depressing the entering pathways so that impulses can not travel along them.

But another phenomenon came to light as soon as electrical studies of the brain became practical, one which, despite earlier evidence suggesting it, was not entertained seriously by physiologists; and the new findings are leading, in my opinion, to a major revolution in our ideas of the physiology of the nervous system. It is observed that, even when no stimulation is applied, when the optic or auditory path or that from any other receptor is not deliberately excited, there is, nevertheless, a continuous electrical activity exhibited in all parts of the brain.

Important conceptual changes concerning the functioning of the nervous system are, in summary form, as follows:

First: The central nervous system was formerly looked upon as a quiescent organ, awaiting excitation, quite capable of responding to incoming nerve impulses, but essentially at rest. Similarly, a nerve was supposed to offer an inert track, into one end of which an impulse entered and from the other end of which it emerged after being pushed or poured or squeezed along by something behind it. Evidence now on hand has established the fact that the nerve itself generates or actively propagates the impulse, as a fuse passes on a spark. The nerve is active, not passive. In the same way the central nervous system must now be looked upon as composed of active units continually in play and which are modified rather than set in motion by particular types of stimuli.

Second: It has been rather the orthodox view that nerve cells were affected only by nerve impulses that reached them or their appropriate processes through the processes of other nerve cells; that only neural connections determine neural activity. Newer evidence forces us to include still other factors at work within the central nervous system, not as alternates but in addition to these neural factors. There is some sort of distance action between nerve cells.

Third: The picture that followed from the previous views was of a static anatomical pattern of activity. What particular reflex behavior resulted on this or that stimulus was determined primarily by which nerve cells were connected with which and what paths were anatomically open to the impulse flowing along. The picture was a spatial one. This is not superseded, but now enhanced by a more dynamic concept. There may be physiological patterns, depending on functional state and relative condition of masses of neurones, which determine activity. What is the evidence for these heresies?

We are familiar with the spontaneous automaticity of the isolated heart or gut and the regular act of respiration. In the case of the gut, the automatic beat depends upon the presence of nerve cells, for if the two muscle layers are separated the nerve net goes now with one now with the other and only the layer possessing it continues to contract. In the heart, also, the nodal tissue is the pacemaker and, whether this be regarded as true or modified nerve cells, essentially the beat does originate in some sort of neurone, though the heart muscle may also manifest automaticity. Finally, the respiratory centers in the medulla and brain stem discharge impulses down the phrenic and intercostal nerves at regular intervals. It has been argued that certain afferent stimuli set them off at the appropriate time though however, many afferent stimuli were eliminated these discharges persisted, as if the cells were automatic. Yet, most physiologists failed to make the apparently obvious generalization that nerve cells as a class might possess the property of automaticity. It seems probable that most neurones, under conditions reasonably normal, are able to beat spontaneously, just as in the case of the heart.

Some old experiments on the spinal cord are of interest. Motor nerves, as measured by their electrical changes, are more or less continually, but irregularly, active. It is hard to make much out of it. On anesthetizing the sensory part of the cord these discharges do not stop, as they should if they depended primarily upon reflex connections, but the motor cells continue a very regular discharge at about forty impulses per second. The discharges in phrenic nerves, interestingly enough, are timed alike in the two, coming from cells on opposite sides of the brain.

If an electrode is placed in the optic pathways in the brain, one is likely to note a perfectly regular electrical discharge, or a potential rhythm, giving

clear waves on the oscillograph and sounding as a "pulse" from the loud speaker. This rhythm in the cat is two to four a second, in the rabbit three to five, and what is presumably the same rhythm in man's brain is at ten a second. In fact, in the human this rhythm completely dominates the whole brain, because man's optic system is relatively far more important than that of more primitive animals; so that it is possible, by placing electrodes on the front and back of the head without opening the scalp, to see or hear this continuous chugging away of the brain, at ten beats a second. These rhythmic discharges are, in most cases, not enhanced by optic stimulation, but on the contrary, are decomposed or abolished. With light shining in the eye the rhythmic potentials disappear, to return again in the dark. Different regions of the cerebral cortex of animal brains have potential patterns more or less uniquely characteristic of each. The cerebellum gives, similarly, characteristic, though more rapid and otherwise different, waves.

When the cerebrum is allowed to remain relatively undisturbed, when by one means or another afferent impulses to the cortex are minimized or abolished, then these rhythmic potentials are not decreased but regularly increased. During sleep, for example, they tend to become much larger, slower and rather more regular. A person kept awake for some fifty hours, who can fall well asleep and be awakened at minute intervals, shows such changes quite sharply. Under the action of certain types of anesthetic, which are claimed to act by blocking afferent connections, these potentials likewise become larger and more regular; and when the brain is protected from afferent impulses by severing most of its connections with the remainder of the nervous system, again these large potentials dominate the picture.

From another source also there is evidence that nerve cells can spontaneously discharge. Observations on salamander embryos show that spontaneous movements may occur before any reflex ones can be elicited. And in goat embryos, before reflex connections exist, there appear regular fluctuations in the heart rate due to discharges from the medulla down the vagus nerve.

Another observation, previously unexplained, becomes clear if neurones can manifest spontaneous activity. In a "decerebrate" cat, when the spinal cord is cut below the region from which the nerves to the arms come, certain muscle groups become more contracted and the arms consequently rigid. Impulses ascending from nerve cells lower down in the spinal cord are acting upon those in the arm region. Yet when all the lower nerve roots are cut, so that there are no nerve impulses reaching these lower cells they still discharge, for cutting the lower cord away still brings on rigidity in the arms.

The final and conclusive evidence that nerve cells can spontaneously and automatically initiate an electrical beat comes from observations made on isolated masses of neurones. Adrian removed the brain of a goldfish and found regular potential waves occurring in it at one a second, the rate at which the animal breathed, so at least breathing discharges originate in the isolated brain. Other experiments have shown regular discharges from isolated ganglia, for example, in the caterpillar and the squid, and very recently it has proved possible to remove the brain of a frog to moist cotton and obtain from the olfactory portion a very marked regular potential wave at five a second. Since no potentials can be seen in the olfactory nerves coming into this end of the brain nor in the main mass of the cerebrum behind it, there seems to be no chance of the rhythm being due to impulses from cut nerves or elsewhere; it must arise in

the neurones *in situ*. The individual neurone must possess the potentiality of beating automatically.

Several questions arise at once. Are these rhythmic changes in potential associated with the discharge of nerve impulses and are they slow because the rapid potentials accompanying nerve impulses are grouped so as to pile up into a slow one; or are they truly slow changes in the charge on the nerve cells, possibly not associated with a discharge of impulses? What are the factors that control the beat of the nerve cell; are they similar to those that control the beat of the heart or quite different; are they neural, chemical or physical? Finally, is there one set of factors acting on all nerve cells alike with only quantitative differences, or may there be many qualitative species of nerve cells with different types of control? These and related physiological questions, too involved for inclusion here, are well discussed in volume 4 of the Cold Spring Harbor symposia.

The second major question or thesis propounded is: how do the many individual nerve cells interact together? It is certain that in a great many cases large numbers of neurones in a relatively small mass of brain tissue are beating together, are discharging their electrical potentials in unison. If that were not true, even with our best modern electrical methods, we should rarely be successful in obtaining anything beyond extremely irregular and small potentials and a most disconcerting picture of what is going on. It is only when a great many individual units are acting together so that their small voltages sum in magnitude, while not being scattered in time so as to cancel one another, that we can obtain these large potential waves. What leads to the synchronization or the asynchrony of related nerve cells? Unquestionably neural mechanisms contribute.

In the passage of nerve impulses between various cells, or into the general felt work of interlacing nerve fibers, the so-called neuropil, there are ample possibilities of coordination and there is evidence that they are realized. For example, the part of the frog brain showing the best rhythm is also the part with the richest neuropil; and cutting connections between cell masses will sometimes change the rhythm in each. Such transmitted nerve messages, however, are not the whole story and it becomes ever more doubtful that they constitute the most important control. There is, in addition, some distance effect—some action of one cell on another quite aside from the actual passage of impulses between the two units. Some of the evidence for this has already been hinted at and more follows.

Under conditions, as in sleep, narcosis or isolation, when the activity of cells should be least coordinated if they are discharged by an inflow of impulses, one finds the largest, slowest and most regular potentials—as if the cell units had become more completely synchronized. In the case of the optic rhythm in man, there is evidence that it centers in some one region, which, however, is not fixed anatomically but may wander about the cortex with varying degrees of latitude. As long as a spacial shift in the brain may occur, no particular nerve cells or connections can be indispensable, and it becomes a matter of suspicion whether local connections of any kind are essential. Again, under the action of strychnine or other convulsant drugs, the potentials become very large and widespread and may move across the cortex in a slow wave, far more leisurely than if conducted by any kind of nerve fiber with which we are familiar. Further, they may gradually grow or fade or make a sudden jump at the junction of two structural regions, but not following known or well-defined pathways through the cell masses. Also potentials in one

region of the brain may be profoundly modified by a small injury to a far-removed portion of the cortex, which has no particular anatomical connection with the first.

These, however, are all rather minor inferential bits of evidence individually explainable along standard lines. There is more direct evidence available when we turn again to the potential changes observed in various sensory pathways. There are two regions in the brain where auditory and optical pathways are very closely related. It is possible, therefore, with an electrode in one position, to record responses to sound, the ticking of a watch, and at the same time to light. The observation has been made that while the eye is illuminated and the optical system active there is a definite increase in the sound response in the auditory system. This is not due merely to nerve impulses leaking over from the optic pathways into the auditory ones, because the activity in the auditory path retains its original wave shape and other characteristics, only its intensity is greater. Here is an interaction which does not depend upon the actual interchange of nerve impulses.

Further evidence comes from the spinal cord. It has been found that certain nerve fibers which carry sensory impulses into the cord do not end there by making connections with other nerve cells but continue through its mass and again emerge. Nerve messages coming from a sense organ may, therefore, run into the cord, through it and out again without having encountered any synapses. The evidence that only typical conduction in a nerve fiber is involved is rather satisfactory. Nevertheless, although impulses may enter the cord in this fiber with the utmost regularity, when they come out again in the same fiber and at the proper time, groups of them have completely dropped out. Somehow or other a through nerve fiber can be blocked in the cord. This is difficult to reconcile with the ordinary concepts of neural control at synapses, and the like.

A last line of evidence comes from the eye, whose retina is really a bit of central nervous system. When the many thousand receptors in it are uniformly illuminated, all the neurones discharge in perfect unison; but if only a few are stimulated differently, not only the nerve cells connected to them get out of step, but the entire formation is destroyed and all the cells discharge chaotically. This, I believe, can not in any reasonable way be squared with the orthodox mechanism —of nerve impulses traveling particular paths to make particular connections. Some additional mechanism is needed.

Nor is there lacking much other evidence of synchronization of units by some sort of non-neural distance action, even though its exact nature remains obscure. The spirited discussion in *Science* regarding the synchronous flashing of fireflies is relevant. Large numbers of grouped individuals come to flash simultaneously, not as a progressive wave of "follow the leader" activity. A pleasant and profitable post-prandial half hour can be spent on a pier observing similar phenomena in a school of minnows. Here several hundred fish may turn, to the fish, sharply right or left or right and left away from some invisible central plane, to form two columns. If some leaders set the mode, the others follow too quickly for my eye, though this possibility should be studied with high speed motion pictures. Over at least one hundred miles in any direction, all night-blooming cactus plants in the Arizona desert burst into flower together on some one night of the whole year, though no man has been able to differentiate that night from others preceding or following.

When large numbers of spermatozoa cluster about a single egg their tails often come to lash in unison; possibly some

general potential change is the "distance-actor" here. The same suggestion has been made to account for the ability of cut nerve fibers, lying parallel to each other in a cut nerve and with no neural connections, to get together and discharge simultaneously. In the brain, also, it has been shown that a small constant potential applied across it may bring cells into unison and greatly increase the rhythmic beats. Finally, one may easily observe another example of the synchronization of units. When an audience starts applause each individual claps in his own way and a chaotic medley results but note that after a few seconds, without any deliberate attempt on any one's part, most people are clapping together in perfect time so that a large, slow, regular wave of sound is rhythmically produced. Just so are brain waves built of the added beats of many synchronizing cells.

One more concept, long accepted, is needed before the final picture emerges. The idea of dominance and subordination in groups of individuals, in organisms as a whole, and in various organs is a familiar one; the chairman controls a meeting, a plant grows as the tip of the stem turns, the "pacemaker" near its base sets off the beat of the heart. So in the central nervous system the head end is dominant and tends to hold in check lower portions. If the upper brain is cut from the spinal cord, some spinal reflexes become much increased as if released from some distance control, in this case certainly neural though possibly of a special character ("chronaxie de subordination"). The whole control of body posture, depending on nerve discharges from spinal cord neurones to muscles, is modified from the spinal cord, the midbrain and still more forward brain regions, for following injury to them the legs may become entirely limp or stiffly rigid. The thalamus, below the cerebrum, has to do with affective behavior, and when the cerebrum is removed or its connections to the thalamus destroyed there results a greatly exaggerated expression of emotional reactions. An especially clear case of release from dominance is seen in the autonomic nervous system going to the heart. Two nerve cells and fibers in tandem carry the messages from the spinal cord which speed up the heart. Some messages are continually passing, for if the connections are cut the heart slows. Further, these all start from the first cells in the cord, since whether the nerve between the first cells and the second or that between the second ones and the heart is cut the effect is the same. But if the second cells are left on their own for some days, by cutting their connection with the first group, then they begin to send impulses themselves; for the heart returns to its original speed while connected with them, though separated from the rest of the nervous system, and promptly slows when this final connection is cut. The nerve cells, then, can spontaneously discharge impulses but normally do not do so because they are dominated by a more active region.

If we accept the existence of a spontaneous beat in nerve cells; of mechanisms, neural and by distance-action, for coordinating local masses of cells; and of a still more distant interaction between separate cell masses involving dominance and subordination; then the old picture of a nervous system with a set structural pattern waiting peacefully for nerve impulses to travel through it, like a switch yard set for freight trains, must be improved. Patterns are in time as well as space, dynamic not static, and results depend on the physiological state of nerve cells in addition to their anatomical connections. Even at "rest" there is an active equilibrium—some cells discharging, some beating electrically, others held quiet; by the play upon them of nerve impulses, field potentials, blood chemicals and other still unknown

means of integration. The whole nervous system fluctuates about some physiological balance (reflected in the psychic state as well) and an incoming nerve impulse disturbs this balance in a particular manner. This sets up a new pattern which may relapse to the original or, usually, to some new equilibrium state. To borrow a simile—the nervous system was previously considered as an electric sign with light bulbs wired permanently so as to flash particular words for each switch closed. There are now in use more modern signs, and concepts, which permit patterns to move in time and transcend the spatial structure; and so words move across the sign as individual bulbs flash on and off, while the whole pattern remains intact. Such a dynamic concept of the activity of the nervous system gives us also a possibility of explaining other phenomena, now well established, but inexplicable along more orthodox lines. Some few of these are: the unitary stream of consciousness; the dependence of learning ability on no particular part or connection of a rat's brain, but rather on the total mass left intact; the persistence of strong potential waves in the cerebellum long after a brief stimulation; the finding that neurones in the spinal cord discharge impulses down their nerve fibers to the attached muscle at times characteristic for that particular muscle, so that if the nerve is made to connect with a different muscle the nerve cell discharges at a different time.

Returning again to the orchestra, about to resume after a rather long intermission, the mechanism which produced the music over the radio could hardly have been deduced from the music itself; but knowing what an orchestra is, it is not difficult to understand how the music results. It is not entirely fortuitous that there are rather striking similarities between the action of an orchestra and that of the brain. In each are many individual units, players or neurones, able to produce a spontaneous rhythm. The units are gathered into groups, not all alike qualitatively, and those within one group (say the first violins) are synchronized by some form of distance action. Dominance occurs within groups and, still more, a leader controls and integrates the activity of the entire ensemble. Even the influence of past events on current activity can be seen in both—in written music or mnemonic traces. The violinists and bassoes, each scraping away with his kind, modulating their rhythms to the line of the notes and the baton of the leader, spin out a magnificent pattern of harmony that we call a Beethoven symphony. Similarly, the myriad nerve cells of the brain, as they beat their single rhythms and form and reform their groups and hierarchies, play that greatest harmony of all nature —the totality of animal behavior.

COLOR, FROM SUBSTANCE TO SENSATION

By Dr. FRANK ALLEN
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THE history of theories of color vision is strikingly analogous to the development of ideas regarding the composition of matter. Both subjects sprang from the same period of ancient Greek history and from some of the same philosophers. Throughout the succeeding twenty-five centuries the same spirit of inquiry, first by speculation and latterly by experiment, has endeavored in each case to discover the elements from which the immensely diversified materials and colors of the world are constituted.

The elements of matter were anciently assumed to be first one, then another, and finally all four of the entities, water, fire, earth and air; though at least one philosopher held the extreme and useless view that there were as many elements as there were substances. Under the powerful influence of Aristotle the substances themselves for a time passed out of consideration, leaving only the abstract qualities, moist, heat, cold and dry, to represent them. As such they appear even in occasional modern poetry. To these attributes of elements Aristotle added a fifth, the "quinta essentia"—the quintessence, as it subsequently became termed, the subtle nature of which is most nearly approached by the modern conception of the ether.

The elements, first correctly defined by Boyle as substances out of which nothing else could be obtained, have in modern science rapidly expanded in number until at present ninety-two are recognized which were united by Moseley into a single series by the unbroken continuity of atomic numbers. Further analysis has resolved each element into two basic substances, or electricities, electrons and protons, to which the most recent science has added neutrons and positrons, the elements consisting of such configurations of these fundamental entities as possess the requisite dynamical stability. Under the influence of the prevailing theories of wave-mechanics opinion has now swung to the opposite extreme. Substantiality is denied a second time to the new sub-elements of matter, and a type of permanent undulatory motion of the ether or of space, a wave-packet, which is difficult or impossible to imagine, something that can only be represented by a mathematical equation, is exalted in its place.

In the parallel problem of color vision, the search for the chromatic elements has developed along three sharply differentiated lines. First, the elementary colors were supposed to be three substances, which were inherently red, yellow and blue; second, the elements were assumed to be three different objectively colored lights, likewise red, yellow and blue; third, the elements of color were regarded as three primitive qualities of sensation, red, green and violet. In the case of the elements of matter theory has progressed from substance to motion, while in vision it has proceeded from substance to sensation which, if not an entity *sui generis,* may also be a type of motion.

The earliest of the three ideas grew naturally out of the fact that no method of compounding colors except by mixing pigments was at first known. According to Pliny, the oldest Greek painters used four pigments, white, black, red and yellow, and he supposed that a bluish tint was produced by mixing black and white. Later painters, he adds, used more pigments than the ancients, but with less favorable results. Leonardo da Vinci employed six pigments, the four just mentioned together with green and blue, though he could scarcely have failed to observe that green was produced by mix-

ing yellow and blue pigments which rendered a separate green material superfluous. The mixing of pigments thus easily led to the hypothesis that the elementary color substances were three in number and were red, blue and yellow in hue.

It may be noted that pigments derive their value from their property of selectively reflecting certain colors of the white illuminating light and of absorbing the remainder. With mixtures of differently colored pigments new combinations of reflections and absorptions occur which cause the differences in hue. Such colors, therefore, are due to the subtraction and not to the addition of light. A mixture of yellow and blue pigments, by the subtraction or absorption of colors, reflects green predominantly, whereas a mixture of yellow and blue lights by addition will appear almost white.

As some of the most conspicuous colors in nature, such as those of the rainbow, could not be attributed to the presence of pigments, a vague and incomprehensible idea was imagined to account for them which held that "colors were bodies of which only the names were known."

Recognizing that white sunlight and a dark cloud were necessary for the formation of the rainbow, Aristotle suggested, as an offshoot from the prevailing view, that light and darkness might be the two elements from which by intermixture all colors originated. As light is a form of energy and darkness is the condition of its absence, the doctrine of Aristotle is equivalent to the statement that something mixed with nothing in various proportions produces varieties of something else.

One sentence from a lecture by Dr. Barrow, of Cambridge University, Newton's teacher and predecessor in the Lucasian professorship of mathematics, will serve to show that Aristotle's hypothesis was still in existence after the lapse of two thousand years. "The blue color of the sea," said Dr. Barrow, "arises from the whiteness of the salt it contains, mixed with the blackness of the pure water in which the salt is dissolved; and the blueness of the shadows of bodies, seen at the same time by candle and daylight, arises from the whiteness of the paper mixed with the faint light of blackness of twilight."

The fantastic ideas of Aristotle received a final quixotic exposition in 1810, when they were revived by the German poet Goethe in his work, "Zur Farbenlehre," with the accompaniment of a vigorous outburst of abuse of the Newtonian doctrine of light and colors.

The second idea, that the rays of light themselves were colored, was put forward in Germany by Mayer in 1758 over half a century after the publication of Newton's "Opticks." According to this formerly influential writer, the elements of color were not substances but were three varieties of objectively colored light of the same hues, red, blue and yellow, as specified in the older hypothesis. From this point of view each part of the spectrum must necessarily consist of a mixture of the three elements of color, the variations in hue arising from the different proportions in which the elements were intermingled. By attributing to each of the primary colors the possession of every degree of refrangibility, their separation by the prism was assumed to be impossible.

This hypothesis was strongly advocated in 1831 by Sir David Brewster, the founder of the British Association for the Advancement of Science, on the erroneous basis of what he termed a new analysis of solar light, an experimental investigation for which he was awarded a notable prize by the Royal Society of Edinburgh. So great was the prestige of this distinguished philosopher that nearly the whole scientific world of his time was led astray, Airy, Melloni and Draper, chiefly dissenting. Subsequently Helmholtz showed that Brewster was deceived by the impurity of his spectrum, that is, the spectrum everywhere was mixed with a small amount of diffused

white light. When this undispersed light was removed the misleading appearances vanished. The theory of Mayer and Brewster was an immense improvement upon the ancient idea of the materiality of color. It was also the logical transition from color substances to sensations. Probably it is yet widely held, for it superficially conforms to the primary colors of the artist's pigments, which are still red, yellow and blue. Furthermore, it is difficult to persuade people that the colors of nature in reality have no existence except as sensations in the visual centers of the brain.

Probably the last scientific attempt to maintain the theory of colored rays was made in 1849 by Professor J. D. Forbes, Maxwell's instructor in physics in Edinburgh University. While supporting the hypothesis of elementary colored rays, this scientist admitted the value of Newton's prismatic analysis of white light, but he almost deprecated the discovery because it "complicated" color theory by the introduction of seven distinct spectral hues, whereas, he maintained, the received doctrine allowed and required but three.

The development of the theory of color vision along correct lines had its origin in Trinity College, Cambridge, when, in 1666, Sir Isaac Newton performed his celebrated experiment on the decomposition of white light into its component colors, a discovery that in the opinion of Young "would alone have immortalized his name." Newton himself referred to his discovery of the spectrum as "being in my judgment, the oddest, if not the most considerable detection which has hitherto been made in the operation of Nature." The far-reaching theoretical applications of spectrum analysis to such subjects as astronomy, radiation and atomic structure, as well as the practical application to the design of optical instruments, easily justify the opinion that the discovery of the spectrum, quite as much as Faraday's discovery of electromagnetic induction, may be placed next in importance to the law of gravitation as the second greatest advance in knowledge in the history of physics.

In a single paragraph of unapproachable lucidity in the early literature of vision, Newton strips the mystery from the two older theories and lays correctly the foundation of the origin of color.

> For the rays of light [said he] to speak properly are not coloured. In them is nothing else than a certain power and disposition to stir up a sensation of this or that colour. . . . Colours in the object are nothing but a disposition to reflect this or that sort of rays more copiously than the rest; in the rays they are nothing but their dispositions to propagate this or that motion into the sensorium, and in the sensorium they are sensations of those motions under the form of colours.

Newton realized that only a few primary sensations were required for the perception of many colors. But the clear statement of a competent theory of color vision came a century later when, in 1801, Dr. Thomas Young, director of the Royal Institution, "the last of the men who knew everything," endorsed the ideas of Newton by enunciating his celebrated theory that three fundamental sensations, red, green and violet, were necessary and sufficient to account completely for the vision of light and colors. While for many centuries a triplicity of primary colors had vainly been sought in the nature of pigments and in the character of light, Young found its basis in the constitution of the brain and consciousness. Young's statement of his theory is contained in two or three paragraphs of his papers; yet his scientific fame, doubtless much to his own great surprise if he were living, rests far more upon these few sentences than on the remainder of his voluminous writings on the astonishing variety of subjects of which he was master.

For half a century the theory of Young lay disregarded, partly no doubt because it ran so strongly against received ideas, and partly because the subject of color vision had not then the high scientific

interest and industrial importance which it now possesses. In confirmation of the former of these statements we learn that Professor Forbes pronounced it to be a singular opinion which appeared to rest on no particular evidence and had met with no support. Helmholtz, on the contrary, clearly perceived the greatness of the achievement of Young. After describing many of the intricate phenomena of color vision he said:

> The theory of colors, with all these marvellous and complicated relations, was a riddle which Goethe in vain attempted to solve; nor were we physicists and physiologists more successful. I include myself in the number; for I long toiled at the task without getting any nearer my object until I at last found that a wonderfully simple solution had been discovered at the beginning of the century and had been in print ever since for anyone to read who chose. This solution was found and published by the same Thomas Young who first showed the right method of arriving at the interpretation of the Egyptian hieroglyphics.[1]

In the middle of the nineteenth century Helmholtz in Germany and Maxwell in England simultaneously made Young's theory the basis of their remarkable investigations which removed the subject of vision from the realms of vague speculation and raised it to the status of a branch of science.

Maxwell, in 1855, began the publication of a series of ten investigations and discussions on color vision which placed the theory of Young on a secure mathematical basis. Newton had previously devised a fairly accurate geometrical rule for representing and predicting the colors of compounds obtained by mixing spectral hues. For this purpose he divided the circumference of a circle into seven arcs, respectively proportional in length to the spaces occupied by the colors in the spectrum. The center of the circle represented pure white. At the center of gravity of each arc, small circles were described whose areas were proportional to the intensities of the colors to be mixed. By joining with a straight line any two of these small circles the position of their center of gravity was found. The radius drawn through this point from the center of the original circle cut its circumference at the color which represented the hue of the mixture.

For this cumbersome rule Mayer substituted an equilateral triangle with the colors red, yellow and blue at the corners. The improvement was adopted by Young, who, however, replaced yellow and blue with green and violet. Since this triangle must contain within its boundaries every conceivable color, whatever the manner of its production, Maxwell's first problem was to find a method by which the position of every compound color could be calculated or, what is the same thing, the exact amount of each of the three elementary sensations that enter into its composition. A popular toy, the color top, had long been known in which a circular card painted in colors was whirled round its center. The persistence of vision, upon which the familiar illusion of moving pictures depends, fuses the separate colors into a compound hue. With great ingenuity Maxwell transformed the top into a scientific instrument by painting each of three disks uniformly with a different primary color and fitting them together so as to vary continuously and measure the amount of each color exposed. By alternately whirling and adjusting the disks, the desired hue of the compound color was gradually attained. With measurements of much precision, the first of the kind that had ever been made, Maxwell placed the color triangle upon a firm mathematical basis. A much profounder result than this was accomplished. For, as Helmholtz remarked, he thereby "introduced the relations of size and number into the apparently inaccessible region of colors, and reduced differences in the quality of colors to relations of quantity."

In another respect the investigations of Maxwell were of notable importance.

[1] From the inscriptions on the Rosetta Stone.

He was the first to derive the color sensation curves which are the most fundamental measurements in vision. These curves represent the exact amounts of stimulation of the three elementary color sensations which are required to produce every hue in the spectrum.

In view of these investigations, for which, in 1860, the Rumford Medal of the Royal Society was awarded to him, it is not too much to claim that by his profound insight and great experimental skill Maxwell laid securely the mathematical foundations of color vision. To these achievements Helmholtz added his own extensive researches, and wove the whole theory of vision into a philosophical treatise that is still the greatest work upon the subject. During the last seventy years, many scientists in the chief countries of the world, but especially in Great Britain, Germany and America, have immensely developed all aspects of visual research. Parallel with these investigations, which are still rapidly expanding, have grown the great color industries of the world and the development of the marvelous methods of illumination, with the necessary invention of efficient sources of light and color.

Probably a hundred other hypotheses of color vision, in which the elements of sensation have varied from two to nine, have been proposed during the last century. With the great majority the papers announcing their birth were also their obituary notices. Some three or four of them still enter into the controversies on vision; but none has shaken the basic principle of sensational trichromasy founded by Young and established by Maxwell and Helmholtz, nor has any other contributed so impressively to the theoretical and practical developments of color perception and illumination which hold so large a place among the triumphs of modern science.

The retinae of the eyes are in reality portions of the brain extruded to the surface of the body. Upon these exquisitely sensitive organs the optical systems of the eyes automatically focus with high precision the images of objects far and near within the hemispherical field of vision. The images which are of immediate interest are made to fall clearly on the centers of the retinae, while others of less regard are distributed indistinctly over the periphery. The tiny central areas of distinct vision, which are the chief portals of knowledge, are smaller than the head of a pin, yet by the sensory power of the brain their images are clothed with delicate gradations of light and shade and the indescribable charm of color. Infinitely transcending the magnitude of its organs, vision invests all nature with illumination and floods consciousness with light and color.

Vision is the meeting place of the sciences of physics, anatomy, physiology and psychology. Here also the mathematician finds ample scope for his rigorous analytical skill. The philosopher must weigh the arguments on whether the perception of space is innate as a property of mind or is empirically derived from the sense of vision with some assistance from that touch. The artist plans his color schemes to impress the eye, while the sculptor and architect associate grace and dignity of line with surface and volume for the same organ of vision. The inventor devises new sources of light which the illumination engineer effectively employs to meet the exacting requirements of sight. The educationalist, realizing that nearly 90 per cent. of knowledge comes through the eye, perfects new optical aids to instruction. The craving for entertainment is increasingly satisfied with visual illusions by motion pictures. All science and industry, even civilization itself, rest upon light and vision. In their loftiest sense they are the symbols of intellectual and spiritual life.

OCEANOGRAPHY: MARINE ZOOLOGY

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Oceanography is the science that coordinates the results of research done in all branches of science, as these pertain to the ocean, its contents and its boundaries. As such, it is of recent development. Isolated scraps of information concerning the ocean have been accumulating from the earliest days, but as long as men and women of science felt that it was necessary to work in water-tight compartments, and as long as they felt that it was beneath their dignity to take any notice of work done in other fields, coordination of this information for the benefit of all was out of the question. The days of such exclusiveness are pretty well gone, so much so that it may be said that the most striking single feature in the progress of science in the present century is the spirit of cooperation and coordination.

Oceanography, therefore, is largely a product of the present century; Pacific oceanography, largely that of the last two decades. There was no real cooperation in Pacific work before the First Pacific Science Congress in Honolulu in 1920. The growth since that time has been very rapid, so much so that at the fifth Pacific Science Congress in Vancouver in 1933, Dr. Vaughan could speak with authority when he said that more had been accomplished in Pacific oceanography during the preceding four years, 1929–33, than in all previous time.

Since that time grants for oceanographic research have been severely reduced in almost every country interested, so that expansion at the same rate has been out of the question, but by using the funds available to the best advantage, excellent progress has been made.

Since all the sciences contribute to oceanography, and since, when coordination takes place, it is difficult to decide as to the contributions of each, because, in many cases, two and two make much more than four, and there is really no necessity for or value in making such a decision, how may one speak concerning the position of any one contributing science?

In some respects marine biology may be considered to be the center of gravity of oceanography. Largely because man is a living organism, living organisms everywhere have always been of enduring interest to mankind. The applied science of navigation has been of immense importance all down through the ages, but, except for the skilled few who are actual navigators, scarcely any one knows or cares anything about what it all means, even when he is reaping the benefits.

On the other hand, what traveler is so blasé that he is not at times stirred to activity by the cry "A whale!" or who is there who has never been thrilled by the amazing stories, sometimes true in part, of the fiendish depredations of the man-eating shark, the terrorizing flying leaps of the giant manta, the irresistible embrace of the gluttonous octopus or the subtle evasiveness of the undulating sea-serpent!

For a great number who have never seen the sea, the ocean is of interest because it is the reservoir for such vast supplies of food and other necessaries of life, the constancy of which depends so much on the proper balance between exploitation and conservation.

For all those interested in organic evolution, the ocean is of interest because it was the home of the ancestors of not only the present marine inhabitants, but also all the inhabitants of the fresh water, the land and the air.

Much of the research possible on marine organisms, in anatomy, embry-

ology, histology, etc., may not seem to have much bearing on general oceanography, but in life-history studies, little or no progress can be made without involving almost everything that is included in oceanography, since the most vital phase of such investigation is distribution and the conditions on which distribution is based. This applies to both plants and animals, although, largely on account of the necessity for sunlight in photosynthesis, the distribution question is somewhat more restricted in plants than in animals.

Within certain limits, there may be a definite parallelism in the tolerance to variation in living conditions in plants and animals, *e.g.*, along the coast of British Columbia, the conditions of temperature, salinity, etc., that suit the large vine kelp, *Macrocystis,* seem also to suit the small red abalone, *Haliotis,* equally well; so also, *Phyllospadix* and the barnacle, *Mitella,* appear to thrive well as neighbors.

In considering the distribution of animals, they may be placed in either of two large groups or divisions: (1) those that are attached or sedentary for the greater period of their existence (almost all species of animals move freely during some period of their life); (2) those that move about freely much of their lives.

In order to live, the stationary individuals must be located in such a situation that food may be provided and that all conditions may remain within the limits of tolerance throughout the whole period of stationary existence. The degree of tolerance, however, is an individual characteristic, and hence information on the limits for one species may help little in the consideration of any other species, unless the possibility of association is known. In some instances the limits are evidently far apart. The hydroid, *Sertularella tricuspidata,* is distributed over much of the polar and temperate areas of the ocean, and from at or near low-tide to a depth of 1,800 fathoms. On the other hand, one of the phoronids, *Phoronis vancouverensis,* has been reported only from a restricted area in and near Departure Bay, B.C., with a bathymetric range of but a few feet around the low spring tide line. (In passing it might not be amiss to remark that it is always unsafe and often very unfortunate to make the statement that any species does not inhabit a certain region, simply because the author of the statement does not know of its occurrence there, especially if he has not taken the trouble to look up the literature on the subject.) The "age and area" conception may account to some extent for these differences in distribution, but it doesn't tell the whole story.

The motile species bring in other complications. If conditions in any one place become unsatisfactory, they can move to some more suitable location, and these movements require much observation and investigation.

Migration may be quite definitely periodic, or it may seem to bear no relation to any definite periods. The most common periodic migration is the migration preceding reproduction, commonly known as spawning migration. Such a migration may be geographic or bathymetric. If it is geographic it may be for but a short distance, *e.g.,* from deep water to shallow or inshore, as is the case of the moonshell, *Lunatia,* and many more of the mollusks, or it may be for a great distance, as that of the fur seal from the California coast to the Pribilof Islands in the Bering Sea.

Bathymetric migration is illustrated by many of the annelids, as the Nereids and the Syllids, and of the smaller crustacea, Copepods and Euphausids, that remain at or near the bottom of the sea except when they come to the surface to spawn. This spawning migration is often associated with segregation.

It may be that migration is made in order to follow the food supply, which may mean that the food supply migrates also, but in following this up there must be an ultimate food supply, the indi-

viduals of which do not depend on highly organized food, and some other explanation then becomes necessary for the migration. Such migration is not likely to show any definite periodicity and it does not necessarily induce segregation, although it may do so.

Other irregular migrations on a large scale are still harder to explain. The siphonophoran, *Velella,* regularly inhabits the Pacific between the coast of the mainland of the United States and the Hawaiian Islands and may commonly be seen in myriads in this area. In the summer of 1926, large numbers migrated northward along the coast of Vancouver Island and even off the coast of the Queen Charlottes, numbers such as never have been reported before or since.

Even more puzzling is the sudden segregation of such numbers of a single species of Protozoan (different species appear on different occasions) that the water is clouded and colored in patches, small or large, with practically a pure culture of the species. They seem to appear out of the blue, all in a few minutes, remain in evidence for a few hours at most and then disappear as suddenly as they appeared.

Is any one working in biology alone, *i.e.,* biology in a restricted sense, going to solve any of these distribution problems? No chance. He will need the cooperation of men working in all the other phases of oceanography, and even then there will be no end to the problems.

In attacking these problems, possibly the cooperation of the chemist and the physicist is most essential or most fundamental. Whether the most of the elements that go to make up the animal body are obtained directly from the sea-water, or whether any of them are, it makes very little difference to the question here. They must be present in the sea in some form and they must be available directly or indirectly for the use of the marine animals. In most cases they are transmitted, in the ultimate analysis, by means of the plants, possibly most commonly through the diatoms and their unicellular allies, but the possibility that bacteria play an important rôle must not be left out of consideration. Marine bacteriology is only beginning to play its essential part as an oceanographical adjunct, but promises to be a real feature at no very distant date.

The presence or absence of not only the major elements, as carbon, oxygen, hydrogen, nitrogen, phosphorus, sulphur, but also those of which only a trace is needed, as iron, copper, manganese and the compounds of these in such form as can be transmitted, must be determined by chemical analysis, checked up by biochemical methods, to learn what conditions are suitable for the life of each organism. Furthermore, the physiological processes of the organism may be dependent upon the degree of salinity, alkalinity, etc., of the medium in which the animal lives, and the interaction between the organism and the medium comes into consideration.

Certain physical features are perhaps of just as much importance. Temperature, light, density, pressure, come strongly into functional control. While with most species, if not all, there is an optimum for each of these, this optimum differs in different species. In some cases, it may be far from the maximum and the minimum that may be endured; in others, there may be a very narrow range.

A single physical, chemical examination at any location tells a very small part of what is required. It must be repeated at intervals throughout the day, throughout the year, and in many cases, year after year, especially in such waters as Puget Sound and the Strait of Georgia, since conditions here may change so much during the year and may be different at the same time of the year in succeeding years. To find the conditions necessary for migration, in particular, such a procedure is the only one that offers any promise.

There may be a critical period or critical periods in the life-history of an animal, when it is necessary to have the range of variation much restricted. The razor clam, *Siliqua patula,* can stand sea temperature nearly to zero, but it will not spawn until the temperature of the water reaches 13° C. The Pacific herring, *Clupea pallasii,* spawns readily in the shallow water in the open sea, when spawning time arrives, but the spawning may be stopped if it is impounded, even if it is still at liberty to swim about freely.

It is not enough to thus obtain so much significant data; the reasons for the changes in physical, chemical conditions should be discovered, hence, meteorology, hydrography and hydrodynamics must enter into the investigation. Air pressure and temperature, winds, storms, tides, currents, wave action, all take part in changing these conditions, and hence in determining distribution.

Where currents pass to and fro through narrow channels, the continuous interchange of water bearing food material makes the conditions along the shore and in the shallow water suitable for many attached forms and motile forms that use these for a food supply, forms that could not live in the quiet waters of sheltered bays or more particularly in deep fiords that have a shallow threshold. The heavy surf of the exposed coast may make it practically impossible for sessile forms to remain attached or to become fixed in the first place, although the water may contain more than the necessary supply of food.

The nature of the contour of the coast, the effect of fiords, the depths of the sea, the change of the tides, the regularity or irregularity of the sea-bottom, the nature of the bottom, the amount of mixing of the deeper and the shallower or surface water, all have direct bearing on distribution.

By considering the details of a good hydrographic chart, it is possible to conclude quite definitely what areas promise well in which to dredge for any particular species or association of species. Furthermore, when the dredge is being hauled along the sea bottom, by putting the hand on the cable, it is possible to judge if the desired area has been located.

Closely associated with these, especially with hydrography, geological evidence is of much importance. The nature of the rock formation along the shore and in the sea bottom has much to do with the distribution of attached forms in particular. Sandstone and limestone, since they wear with wave action, are more likely to have the irregularities necessary for the attachment and protection of these forms. Shale may break away enough or split off to give the necessary shelter, but traprock or granite is too unyielding to serve satisfactorily.

Shingly beaches, when exposed to swift currents at high tides, may harbor great numbers of organisms, if the rocks are not too bare, too isolated or too much embedded. Beaches of sand that is not too fine, or too free from clay particles, may make a suitable home for many of the mollusks and annelids.

The nature of the shore has so much to do with the biological distribution that one somewhat familiar with the region may pass along some distance off and, with field glasses, decide quite exactly the type of animal associations he is likely to find on each portion of the shore.

Geological history of the earth may give distributional evidence on a much larger scale, since the change of elevation of the surface in certain areas may erect barriers to distribution, or, in other cases, make free distribution possible.

A recent opportunity to collect hydroids from the Galapagos Islands and the mainland coast of the Pacific from Guayaquil to San Diego, an area not previously explored for that purpose, made it possible to see the marked affinity between the hydroids of this region and

those of the West Indian area. This might be difficult to understand if the geologists had not determined that at one time there was no barrier to hydroid distribution between the two regions. This indicates, as well, that the species common to the two regions are quite old species. It is not surprising, then, to find that about 40 per cent. of the species obtained are new species.

Of recent years, statistics, as applied to oceanography, have come much into the public eye, through the use that has been made of them in determining the balance between exploitation and conservation of species commercially valuable, in order to be able to regulate the exploitation so that the value of the species may be retained. It is only by the analysis of reasonably complete and accurate statistics of the catch from year to year that any satisfactory regulation can be applied. By reason of this, the distribution of the species during the different stages of its existence is determined.

Such distribution studies can be applied just as well to other species, not now commercially valuable. In this part of the world, where, commonly, there is a decided difference in rate of growth in the winter season and in the spring and summer, it is often possible to determine the age and rate of growth by examining some of the skeletal features that show the winter check, as, for instance, the scales and otoliths of fishes and the shells of mollusks. In the animals of the tropical seas, where there is eternal summer, there are no such checks, and statistical examination of large numbers of the species is, at present, the only satisfactory method of obtaining the necessary information.

It must not be inferred from all this that the marine biologist is a mere mendicant, holding out his hand for assistance from all the other scientists. He is able and willing to give much in return. The benefit is reciprocal. The information he obtains concerning life-history and distribution of various species can be made use of by indicating the conditions, chemical, physical, etc., where these species appear. This is more noticeably true when the species is large or abundant but may be of importance in any case.

The study of the growth and distribution of corals and nullipores to form islands, reefs and atolls has received great attention in that regard. By their narrow range of tolerance to changing conditions and by their extensive multiplication within this range, their presence or absence in any location tells quite a story in itself. They must have the water at tropical temperatures. A stream of fresh water emptying into the sea may interrupt their extension, *e.g.*, it may make a passage of open water through a barrier reef. Various theories as to subsidence and the relation of land masses have been based on their presence and their growth. Some of us would be interested in an explanation as to why there is one atoll (Clipperton Island), and one only, in the eastern tropical Pacific.

In this part of the world, the bull kelp, *Nereocystis*, is so definitely associated with rocks, reefs and rocky shoals that during the summer months it is of great aid to navigation of small craft in shallower waters.

The distribution of brachiopods is used extensively in determining relationships of land masses, small and large.

It is not necessary to go farther. The ocean is full of examples.

Since, therefore, bacteriology, chemistry, biochemistry, physics, meteorology, hydrography, hydrodynamics, geology and statistics, with other sciences that might be included, must come to the aid of biology in solving marine problems, and biology must come to the aid of each of these as well, it is surely "all for each and each for all." And that is oceanography.

IN PRAISE OF PARASITISM

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At the outset I wish to emphasize as strongly as I can that in this discussion I am not interested primarily in parasites but in parasitism. One may praise parasitism without eulogizing the parasite. Parasites, however, have often been eulogized, *e.g.*, that fleas are good for a dog. The proclaimer of this profound and time-honored observation was ostensibly interested in canine welfare, *i.e.*, as man in his infinite wisdom understands it. No one has yet told us what the dog thinks about it. Said proclaimer might also, with equal justification, have added that dogs are good for fleas, but, although this is undeniably true for at least some dog-inhabiting fleas, he is not in the least perturbed over the well-being of fleas, generically or specifically. Nor does he say that fleas are good for men, even though in modern folklore they are said to accelerate the vocational activity of one-armed paper-hangers. Such fleas are too close to home to admit of unchallenged approbation. I am not attempting to defend or justify the ethical behavior of a parasite. I am simply emphasizing the fact that I am not interested in human ethics when applied to fleas or parasites in general. This may be said, nevertheless, in passing, in defense of every parasite: However its moral status may be judged in such terms of human ethics, it has achieved something, at least, in the way of economy of effort in making a living, and it has demonstrated a high degree of exactness in its adaptation to an unusual complexity of biological environment. Perhaps it was merely an unconscious racial or nationalistic urge to applaud this achievement in economy that induced the celebrated Robert Burns to immortalize in verse the lowly louse, a pariah even among parasites, and which he describes as

> Ye ugly, creepin', blastet wonner,
> Detested, shunn'd by saunt an' sinner.

He even selected as the locus for his exhibition a lady's hat—a beautiful and expensive setting—and he sanctified the performance in the devotional atmosphere of a church service. Note in his opening verse how Burns's genuine admiration refuses to be totally concealed by his natural antipathies.

> Ha! whaur ye gaun, ye crowlin' ferlie!
> Your impudence protects you sairlie;
> I canna say but ye strunt rarely
>   Owre gauze and lace;
> Tho' faith! I fear ye dine but sparely
>   On sic a place.

Then after six stanzas of the exciting adventures in and on milady's Sunday millinery comes the immortal closing stanza:

> O wad some Power the giftie gie us
> To see oursels as ithers see us!
> It wad frae mony a blunder free us,
>   An' foolish notion:
> What airs in dress an' gait wad lea'e us,
>   And ev'n devotion!

A verse packed with serious thought for every scientist. Perhaps the use of a parasite was merely a coincidence—or was it the potency of Burns's favorite "highland dew"? I prefer, personally, to think that the jovial Scotch bard caught something of the parasite's view of man; he got a louse's view of man and found it more honest than a man's view of a louse; he saw "oursels as ithers see us" and found our "notions" and "even devotions" ridiculous. To him, a louse is good for man—it keeps him from brooding too much on his worldly im-

portance—one of the notions that man so immensely exaggerates—and that's, to begin with, something to be said for parasitism.

In the truly more humble spirit of Bobby Burns let us consider the importance and the tremendous contributions of parasitism to biological evolution. The decalog has no place in this evolution of parasitic relations. Man is nothing more or less than one of the most complex of the products of evolution. Indeed, he, himself, is merely one of the famous and successful parasites of all biological history. A louse is a louse, a flea is a flea, a bacterium is a bacterium, and ill does it become man to belittle the dignity and achievements of these venerable and distinguished orders of fellow parasites. The world revolves just as much about the louse as about man. Man's egotistical assumption of his place in the sun as the end and aim of cosmic evolution is responsible for the prevailing ethical prejudice against parasites and for the distorted concepts concerning the real importance of parasitism. To sum up in the language of our legal brethren, teleology and ethics are irrelevant, immaterial and inconsequential as evidence in this discussion.

Of course, it becomes necessary at the outset to define our terms. What do we mean by parasitism? Broadly defined, it is a condition of intimate association between two organisms, *i.e.*, living entities in which one organism, the parasite, lives on or in the other, *i.e.*, the host, and derives a part or all of its food from this host. The effect of this association is frequently injury, or even death, to the host. In other cases, however, no apparent injury is sustained by either organism. In extreme cases the association may seem to be indispensable to both organisms. These mutually beneficial associations are termed "symbiosis." But between symbiosis and parasitism there can be drawn no sharp line of demarcation. The transitional nuances from serious injury to slight injury, and then to no injury, and finally to apparently mutual benefit are gradual and continuous. Moreover, even in the classical examples of mutualistic symbiosis, one of the partners in the association is more or less independent or dominant, and, finally, there is much evidence that all such cases of symbiosis are evolutionary developments from true parasitic associations. For our purposes, therefore, symbiosis may be regarded as mutually beneficial partnerships arising from and due to parasitism.

The definition of parasitism is not complete, however, without a consideration of its relation with the associations of organisms known as saprophytism. Saprophytes are organisms (in a strictly literal sense—plants) deriving their food from dead organic material, in other words, from the dead remains of preexisting plants or animals. In the last analysis these saprophytes and scavengers are just as dependent on other organisms for their subsistence as are confirmed and orthodox parasites. The essential point is that they too derive their food from other organisms. By well-learned economy of effort they find it unnecessary to manufacture their own food from inorganic minerals, water and air, as do the plants called autophytes, but start with such food, previously prepared by other organisms, and adapt these to their own use. Between parasitism, in the technical biological sense, and saprophytism are crowded innumerable gradations so that one shades off imperceptibly into the other. Some are weakly parasitic and predominately saprophytic; others are strongly parasitic and weakly saprophytic. At one extreme are obligate parasites, *e.g.*, rusts of cereal, which can be grown only in their parasitic relationship on the living cells of grain plants, and at the other extreme are obligate saprophytes, such as our common mushrooms, which grow only on dead remains of other organisms.

The essential feature of the phenomenon which we call parasitism is the derivation of already elaborated food by one organism from another organism. Always there is this nutritional interdependence. It is common to the whole gamut of phenomena, which range from mutualistic symbiosis, on the one hand, through the multitudinous types of orthodox parasitism, to all forms and types of saprophytism at the other extreme. It is always predicated on an already existing or a pre-existing organism as a host or source of food. It always involves the establishment of a food habit in the parasite, which is not independent of other organisms but dependent on them. It is a nutritional dependence in a social structure. It is a departure from the individualism of the autophyte, which makes its own food from the rocks and water and air and which is socially independent of all other organisms. And it is this basic and comprehensive feature of parasitism in its broadest sense that has had an incalculable effect on biological evolution. Its exploitation has resulted in theft and robbery of every description, even in the destruction of individuals and whole races of organisms. It has appeared and reappeared in the long history of living things in every conceivable form and degree. But it has not always been destructive. Under fortunate use it has been not only beneficial but even indispensable to progress. It has made possible the development and has been an indispensable feature of all the higher plants and animals that exist in this age of biological history. Without this fundamental physiological phenomenon, none of our mammals or seed plants as they are now constituted could be possible to-day.

That parasitism always involves degeneration of structure or function is a false assumption, based on human prejudice in the interpretation of social values. It is man's view of the louse. Biologists, in more recent times, have become more charitable in their appraisal of such manifestations of parasitism. Structural effects of parasitism, formerly described as degeneration, are now said to be simplification, while the physiological results are often recognized—though sometimes grudgingly—as increasedly complex. But simplification is only a half truth. Why is it that a parasite, like a wood rot fungus, deriving its food from the trunk of a tree, does not form leaves and roots and stem? There is absolutely no need for these organs. The foods which leaves, with their green energy transformers, build up from the inorganic salts conveyed in water solutions and absorbed by the roots and from the carbon dioxide of the air, are ready at hand. What a marvel of economy, efficiency and adaptation to the complex environment of the tree trunk such a heart-rot fungus presents. Thousands of threads, microscopic in width, ramify into a network throughout the entire heart of the tree trunk from top to bottom, disintegrating the woody cells and converting the organic materials manufactured by the tree and laid down in the wood into food for its own use, accumulating and storing it up until ready for reproduction. Then, almost over night, this clever parasite throws all its accumulated wealth into fruiting bodies producing millions upon millions of spores, shot off by marvelously constructed tiny explosive devices through openings adjusted to hair-line accuracy by reactions to the force of gravity. To one who delves deep into the life story of such a parasite, the designation of degeneration of structure is a base libel. To speak of it even as a simplified structure is to be guilty of superficial judgment, because one discovers that those tiny absorptive threads contain chemical laboratories capable of producing more than a score of kinds of enzymes to disintegrate the complex elements of the wood; one finds, moreover, that the nuclear be-

havior of the reproductive bodies exhibits a type of sexuality and an alternation of sex and spore generations rivaling, if not exceeding, in complexity the sex processes of the showy seed plant aristocrats of the plant kingdom. A plant such as this, that has four or perhaps more kinds of sex, is hardly simple! Neither degeneration nor simplification are adequate terms of description for such parasites. Rather are they examples of extreme economy of effort and material and marvels of adaption to a social order that has taken geologic ages to evolve.

How old is parasitism? As far as one may judge, it is as old as the oldest living organisms that exist to-day and must, therefore, have been of very ancient origin. It was certainly common in the Pre-Cambrian era. Bacteria are generally acknowledged to represent the most primitive type of existing protoplasm. It is a fact of extraordinary significance that the modern bacteria are almost universally parasitic or saprophytic in habit—almost, but not quite, since we must not overlook the autophytic bacteria, those existing forms of the most primitive types of organisms known to science. It is obvious that, in organic evolution, autophytes of some form must have initiated those complex continuing chemical reactions which we call life. It may even be that the more conspicuous autophytes or independent green plants of to-day, whose nutritional independence is possible through the agency of the green coloring matter of leaves, which transform sunlight into heat and chemical energy, were a later development and may possibly have arisen from pre-existing and primitive saprophytes or parasites. The first evolutionary development of this green-leaved or chlorophyllous group of plants resulted in the algae, consisting of the green pond scums and sea weeds, where threads or filaments of cells appeared in contrast to the separate cells of early bacterial forms. Parallel with these independent or autophytic algae there was evolved, at possibly many stages in the evolution, parasitic forms in great variety. One of these groups, starting, perhaps, as unicellular parasites in the cells of algae and adopting the same filamentous habit as the algae, produced the water and fish molds and later, when emerging on the land, developed the parasites and saprophytes which we know as higher fungi of to-day: molds and mildews, rusts and smuts, mushrooms and wood rots; thousands of bizarre forms of extraordinary structure and habit, known only to the specialists in this field. The high degree of specialization that has been attained by such parasites may be well illustrated by a fungus of microscopic size (a Laboulbenia). It is found quite constantly on one particular joint of one particular leg of one species of water beetle. And yet that same minute parasitic species exhibits not only a segregation of sex plants but also a sequence of nuclear sex history rivaling in an analogous, if not actually homologous, program, the corresponding sequences, *viz.*, alternating generations, of our highest plants and animals. And, most extraordinary feature of all, this tiny, obligate parasite, living under predominately aquatic conditions, has been so profoundly affected by its parasitic evolution that it has entirely lost the automotility mechanism of its sperm cells, although these are transferred in water, whereas in contrast to this loss of sperm motility even in some of the seed plants of to-day, growing under aerial conditions in exceedingly dry habitats, the ciliated self-propelled sperm mechanism of most ancient origin persists. Parasitism has indeed been a most profound force in shaping the form, habits and destinies of organisms.

Indeed, the fungi, which are all parasites or saprophytes, present as a whole a bewildering panorama of parasitic and saprophytic phenomena. They exhibit

almost an infinite variety of form, from microscopic spheres to giant puffballs and exotic toadstools. They vary in habit from intracellular parasitism in single host cells to the rotting of gigantic trees, to the complete destruction of man-grown crops, to a cooperative partnership which makes the rare and expensive orchid entirely dependent on its fungus partner, to the destruction of almost every type of organic material built up in the special chemical laboratories of hundreds of thousands of species of plants and animals, for each of which the destruction involves a complexity of chemical processes comparable to its manufacture. They inhabit every climatic zone; they penetrate on land farther toward the poles than any form of plants or animals; they are found in the tropical jungle and in the sands of the Sahara; they, alone, can wrest a living from the bare exposures of igneous rocks. They have persisted through geologic ages that have witnessed the rise and complete elimination of the gigantic forests and exuberant vegetation of the great Paleozoic; they have adapted their parasitism and saprophytism to the evolutionary succession of plants and animals throughout geologic time.

To apply to them the term degeneration is to judge them falsely in terms of human ethics. Even to call them simple most unscientifically accentuates form and structure without due regard to the economy and adaptation which they exhibit and, above all, ignores their highly complex physiological attainments in an infinite variety of environments.

The two great plant groups of parasites, the modern bacteria and the fungi, began their parasitic careers millions of years ago. The bridge back to independent life—to autophytism—they have apparently burned irreparably behind them. They stand or fall on parasitism. But how about the other plants, that great group of autophytes which also crept out on the land in Precambrian times and evolved the mosses, then the ferns, the pines and other primitive seed plants, and, finally, the great present-day higher seed or flowering plants? Have they too attempted the ways of economy through parasitism? It is a remarkable fact that almost throughout this long succession of plant forms, parasitism has appeared and reappeared in a most varied panorama of forms and habits too numerous to attempt to even enumerate. Many of these experiments in evolution have been unsuccessful—some certainly have succeeded. A few familiar examples from our higher seed plants will illustrate. Remote ancestors of our common morning-glory found that their stems, closely twined about another plant of an entirely different species, made possible the transfer of stem fluids from the plant about which these stems are wound. This transfer was improved by sucker-like outgrowths penetrating the stem of the host. Gradually a complete food supply was possible, and the now-confirmed parasite found leaves and even chlorophyll unnecessary, and thus we have the parasitic family of the dodders of to-day. Even to-day, however, the individual dodder plant begins its life as a seedling autophyte with green seed leaves, but it perishes unless it finds, by weaving its stem around in the air, a suitable host upon which to continue as a parasite. The mistletoes, parasites on apple trees, cottonwoods and pine allies, still retain, in many species, their chlorophyll, a false sign of independence, since they are wholly dependent on their hosts for mineral foods at least.

The Indian pipe of our northern woods is so utterly devoid of chlorophyll and so deadly white that it merits its other common name of corpse plant. Ages ago it belonged to the same family as the blueberry, the rhododendron, the Azalea and wintergreen. We call this family to-day the heath family. The Indian pipe parasitism (more technically termed

saprophytism) is of a quite different origin from dodder. Those ancient blueberry ancestors found their roots invaded by a certain fungus parasite. Apparently some degree of tolerance grew into an established partnership, and this ancestral heath plant came to rely entirely upon the food which the fungus obtained from the organic matter of the forest soil. So complete was this nutritional partnership that the Indian pipe lost every use and vestige of chlorophyll, although it still retains the flower and seed characteristics of its distant relatives. In passing, it may be of interest to note that many species of the heath family, *e.g.,* blueberries, from their green appearance apparently completely autophytes, are, when one probes their private lives, found to have clandestine partnerships with fungus parasites from which they derive nutritional capital that enables them to exist even in unfriendly environments, such as the cold peat bogs of our own climate. Indeed, these partnerships with fungi that feed on soil organic matter not directly available to the prim autophyte, are now found to be common to a great variety of plants and especially trees, where special root organs in which the fungi live are produced. Such a partnership is appropriately known as mycorhiza—a fungus root.

Even more extraordinary are the relations of fungi and orchids. As every one knows, orchid flowers are exceptionally specialized in their insect relations —often adapted to cross pollination by a few or even a single species of visiting insect. One result has been an evolutionary exuberance of orchid species with bizarre and beautiful flowers. Over 15,000 species of orchids are known, but that high degree of flower specialization, together with the highly specialized fungus relations, also results in a comparatively small number of individuals. One may contrast them, for instance, with grasses, which depend merely on the wind for pollen transference and of which only some 4,000 species are known, and yet the grasses cover the prairies and field, marshes and uplands—they clothe the earth—and the orchids are so rare that most of them are known only to the botanist. Indeed, in the exploratory period of botanical science more than a hundred years ago, single specimens of tropical orchids were capitalized under joint stock companies. Now many orchids, when the roots are carefully examined, show no root hairs such as are common to other seed plants. Instead, they have fungus partners analogous to those of Indian pipe and mycorhizae. So well established has this nutritional partnership become that, when the orchid seed germinates, it must soon meet the fungus partner in the soil or it perishes. The seeds are often so tiny as to appear like dust and must be produced in countless numbers to compensate for the enormous infant mortality that inevitably results not only from the paucity of food material due to its small size but also from its highly specialized fungus relations.

We have now reviewed enough forms of parasitism to make clear one basis for a claim for the beneficent use of parasitism. Over and over again in the history of plant life are found such examples of parasitic relationships. Perhaps at one time they were predominantly destructive. Perhaps species and whole families of hosts have been exterminated but here and there the antagonism has been converted by a permanent truce into a mutually satisfactory relation. But, more than that, such established relations now make available to the new partnership new environments and new avenues of evolution. The dodder lives where the morning-glory would perish; the Indian pipe lives in the darkest forest where almost no light penetrates.

To sum up to this point: Parasitism in a broad sense as nutritional interde-

pendence is of very ancient origin, persisting in primitive and in countless evolved forms throughout the geologic ages. Vast groups of organisms, fungi, bacteria and all the animal kingdom are irrevocably committed to the parasitic mode of life. Even among the chlorophyllous autophytes there have appeared and reappeared great arrays of forms which have forsaken their nutritional independence for some special type of parasitism, direct as in dodder or mistletoe or with the aid of fungi, as in orchids, Indian pipe and hosts of others. The prevalence and range of parasitism among the living organisms of to-day are established facts and demonstrate conclusively its importance in past, present and future organic evolution. In the face of these astonishing facts even scientists continue to view these phenomena chiefly through the clouded glasses of human social ethics.

I have introduced this group of parasitic phenomena first because they illustrate most clearly the transition from antagonistic parasitism to mutualistic symbiosis or, at least, to a satisfactory armed neutrality. We have not yet been concerned with whether or not it would be better for organic evolution if parasitism had never been invented. The important conclusion from these outstanding and numerous examples that occur throughout evolutionary history is that parasitism can and has been put to profit and use in meeting new and difficult situations and has been remarkably effective in organic evolution.

And now let us examine into this question: Would it have been better for organic evolution if parasitism had never been invented? To answer this we must turn to an entirely different aspect of parasitism—and here I ask you to keep in mind our broader definition of that term—what the biologist calls heterotrophism, including parasitism and saprophytism. The original living substance was characterized chiefly by an automatic and continuous set of chemical and physical reactions. Expressed in terms of an individual those reactions result in growth of the individual organism; in terms of continuity through the germ cells they result in reproduction. These continuing reactions can theoretically only be limited by the supply of essential elements in available form necessary for the reactions and by the environmental conditions of heat, light and other meteorological factors. The reactions which result in the individual apart from its reproductive contribution to race continuity have come to be limited. Death has become the concomitant of individualization. If individualization, as a diversion of protoplasm from the racial reproductive stream to the fixed elements of individual growth, be a sin or risk against race continuity, then death is indeed the wages of sin. Without death, overproduction of living substance and complete exhaustion of all available substances necessary for life reactions would be a distinct possibility if not an imminent danger. At any rate, death came to living substance and its products. Now comes an important question: What becomes of this dead organic substance? The disintegration of dead organic matter by physical forces, excepting fire, perhaps, is very slow. Wood, not subject to decay, may last for centuries. The destruction of that dead material and the restoration to available conditions of the elements included in its composition would quite obviously be of enormous advantage to the evolving forms of life. Bacteriologists use a standard illustration to the effect that if one placed a single bacterium in the ocean and if that bacterium were to grow to double its size and then divide in twenty minutes (which is a common procedure) and if this process were continued without interruption and without the death of any of the resulting bacteria, all the oceans of the world would be filled in a comparatively short time. Of course

that doesn't happen for several reasons. The possible predicament of early exhaustion of materials by autophytes, the only true individualists in organic evolution, was avoided by a simple and perhaps inevitable development even in the dawn of biological history. The primitive ancestors of our present bacteria probably devised that solution and merit the title of the first great conservationists of all time. Certainly they learned to disintegrate dead organic materials and, in doing so, returned a large part of that material to conditions available for future use. From saprophytism on dead organic material to true parasitism was only a step. But it is quite obvious that such parasitism must, of necessity, require time in which to evolve and adapt itself, and so it inevitably follows that the older forms are more liable to destruction by parasites than those most recently evolved. The evolution of the parasite must lag at least some little distance behind the newest fruit of evolutionary progress. The plant breeder of to-day knows that he must constantly keep ahead of the pursuing host of parasites. Since evolution involves a steady flow of actual protoplasm in all conceivable directions of adaptation, saprophytism is in the long run an indispensable aid in parasitism as accelerator, at least in the mopping up process at the rear of the evolutionary streams.

The decay of tree products, including the branches, trunks, roots and leaves, is practically entirely due to fungi. Only the liveliest imagination can conceive of the vegetation of to-day or of past ages without the scavenger service of the fungi. Perhaps the trees, if any, would have been so tall in order to protrude through the rapidly accumulating debris of branches and leaves that our simian ancestor would never have found it possible to even reach the ground. Or perhaps our even more distant ancestors would never have been able to climb the trees and we might still be sitting with the oyster on the rocks of the ocean bottom.

In the light of these facts, parasitism takes on a new significance. It becomes a necessary check on the increasing and diversifying program of living substance in its appropriation of earth's limited materials. Its ultimate effect is not wanton waste but reclamation and conservation. It permits organic evolution, which can not stop but must go on to traverse again and again the terrain that is constantly being reclaimed or transformed into available habitats for improved organic forms. When the rugged individualism of autophytes has reached the maximum production on the earth's surface, the then existing organic population can be maintained or increased only by the more improved use of parasitism. Parasitism, in its broader meaning, is an ever increasingly important factor in organic evolution.

I have said nothing about animals, and little need be said. They are all heterotrophs and are quickly disposed of, and they would be very quickly disposed of if all autophytic plants were suddenly eliminated or destroyed. All such heterophytic animals, as well as plants, would starve. If this destruction were to include only the chlorophyllous autophytes, we would still have the primitive autophytic bacteria, and evolution would have to begin again where it began perhaps a million years ago. Man is no exception but merely one of the great army of dependent organisms. Indeed, he is the shining example of what the evolution of parasitism itself may accomplish. He, more than any other product of organic evolution, is better equipped to control his environment and to shape his future. Yet he is only a saprophyte (I use the more polite botanical term), and he is more closely specialized in this rôle than we sometimes realize. Could he exist on the flora and fauna of the Paleozoic age if suddenly transported to that era? Men have starved in the forest and

on the prairie surrounded by vegetation. Who can be sure that, in ages to come, he may not become entirely slave to orange juice, spinach and raw milk?

I come finally to some achievements of parasitism which have played a dominant rôle in the evolution not merely of the great succession of land plants from the time of their emergence (from water) to the present but also in the evolution of the highest animals, the Mammalia.

The seed, that modern structure which characterizes the highest orders of the plant life of to-day, was possible only with the aid of parasitism. Moreover, parasitism was called in, not once but twice, in that evolutionary history.

The seed of pine, for instance, consists of three principal parts: (1) the seed coats which are formed by and are a part of the seed leaves of the parent plant, (2) the endosperm, a food storehouse for the third part, which is (3) the embryo plant which lies within the endosperm. Of outstanding importance is the fact that these three parts belong to three different generations. One among many proofs of this lies in the nuclear constitution of the cells. The nuclei of the endosperm have each 1x number of chromosomes (depending on species of plant concerned) while the seed coat nuclei have double or 2x chromosomes. The embryo plant also has 2x chromosomes, but, since it is formed by the fusion of two sex cells (one from the endosperm and one from the pollen tube), it is a different generation from the seed coats. Now the endosperm generation is not autophytic or independent. It is absolutely dependent on the seed coat generation for its food and existence, even though it is a separate generation. Here we have an intergenerational parasitism dating back probably to Mesozoic times when the modern seed was evolved. The second type of parasitism in the seed is, perhaps, more familiar to you. The young plant embryo in the seed has fed entirely on the endosperm generation until the seed is ripe, and even after it breaks open the seed coat at germination it may continue to be parasitic on the endosperm until independently established in the soil. This type of parasitism is much the older of the two and probably arose in the Pre-cambrian geologic era. A very important feature of this type as it exists in the seed is that it is a parasitism confined to infancy. It appeared in the evolution of plants in the mosses where it was and still is a permanent though partial parasitism. In the ferns it became confined to infancy when the parasitic generation as it matured developed roots and was thus able to live at maturity independently in the soil. The first type of parasitism, *viz.*, that of the endosperm on the seed coat generation, appeared in primitive variations among the ferns probably in the Paleozoic age, but was consummated when the three generational units were consolidated into the modern seed of the flowering or seed plants.

Shall we say that it was wicked for plants to produce seeds because such seeds are founded largely on parasitic habits?—or shall we rather acknowledge the marvelous contribution which parasitism has made in the development of that organ which characterizes 90 per cent. or more of the entire vegetation of to-day?

I need now merely refer briefly to the contribution of parasitism to the evolution of Mammalia, the highest ranking order of the animals of to-day. Fetal infancy quite obviously exhibits incalculable advantages in the life of Mammalian individuals. That infancy, often of long duration, is founded on the parasitism of the fetus on the mother, from which the fetus obtains all its food. You are reminded that in that human fetal period more and greater morphological changes in the growth of the individual are consummated than in the entire life

after birth. And all that prenatal growth is parasitic in the broader meaning of that term. Man, in his sociological progress, has found it profitable to prolong that parasitism in a sociological sense into a period of many years by special care, education and training of child and youth—even far beyond the physical stages of adolescence and maturity—even to the completion of a college course or the attainment of a Ph.D. And modern trends of human society are extending that infancy to public support and care of mature and aged as well as infants, of unfortunates as well as irresponsibles, of incompetents as well as competents. If Mammalian orders are truly the aristocrats of the animal kingdom, they owe that position in a large measure to the adaptation of parasitism to their course of evolution.

I have ventured to prove from numerous biological facts and from the experiences of biological evolution that the much disparaged and even despised parasitism has been, perhaps, predominantly a constructive force in plant and animal evolution.

All these considerations on parasitism as a great constructive rather than as a destructive force in evolution challenge our thought as to their significance or connotation in the social evolution of man and especially in the direction of that social evolution. The biological would seem to be the soundest approach to a fundamental consideration of such human social problems. But time does not permit of even a brief discussion at this time. In closing, however, a few important generalizations may be permissible and not out of place.

Interdependence is axiomatically an essential in organized society. Individualism is a rôle in organic evolution that can only be played by the autophytes of the plant world. And even that group must call upon the interdependence which we call parasitism to conserve the earth's food resources by restoring from their gigantic overproduction of organic material that which can be returned and reconditioned for future organic use. Human overproduction of food supplies, in an analogous sense, demands, in the name of true conservation, that interdependence of social groups which we call international trade or its equivalent in order that, by the beneficent use of parasitism, we may reclaim in some form the material or other products into which such interdependence may effectively convert it. Human society, as such, can not safely disregard or ignore the striking lessons of interdependence of individuals or of social units.

To organic life as expressed in the higher plants and animals of to-day, the menace of the complete exhaustion of available food is real. Parasitism in its destructive capacity is a check on the unlimited use and waste of that available food, and in its constructive capacity it is the reclamation of new food materials from the locked storehouses of organic products. Without that parasitism it seems inevitable that these higher plants and animals must approach extinction through increasing unavailability of food materials. It is even conceivable that without that parasitism, organic evolution may come to an abrupt end by the complete exhaustion of food materials. Because of that parasitism organic evolution may approach a succession of building up and tearing down processes that are limited only by the ingenuity of living substance in devising forms of social and individual parasitisms. Living substance may become merely the catalyst in the reconstitution of the earth's solid rocks. But that ever progressing catalysis is dependent not merely on the utilization of the rugged individualism of the autophyte but equally upon the restoration and reclamation of used materials to continued use. I am almost persuaded that parasitism is the great hope of future organic evolution.

THE INSECT MOTIF IN ART

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ART has a background almost as ancient as man himself. This is particularly true of the Orient, where the artist portrayed the spirit or mood of things. They viewed the old masters with reverence and carved, engraved or painted with emotion. The fashioning of the most commonplace trinket or toggle had a profound significance. Such creations had their inception in the ancient traditions of the people, lending a refinement and polish which is lacking in much of our modern art and architecture.

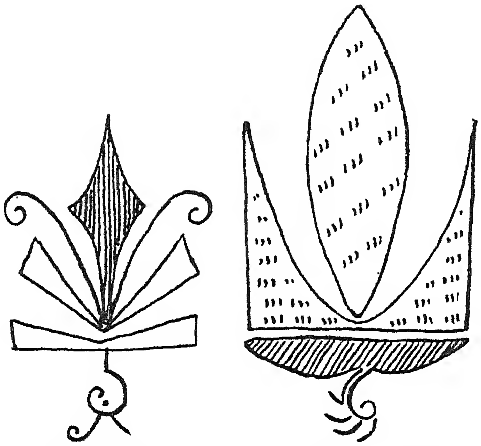
The ultimate sources of genuine art are the myths, legends and folk-lore of the races of the world. Originally these were told and retold among the members of individual clans or tribes. Even today, some races continue to relate these ancient stories, thus keeping alive their rich heritage of folk-lore. Without contact with primitive tribes, many of these tales would have been lost and we would be unable to interpret the significance of numerous motives and patterns which have been used for generations. The double dagger ‡ of the Sioux represents a dragon-fly. This might be guessed because of its vague resemblance to a dragon-fly with outstretched wings. The Hopi and Arapaho use triangles in various forms to suggest butterflies. The explanation may be found in the resemblance of triangles to the scales of the wings or to the wings themselves. When we turn to the highly conventional figures of the Tsimshian or the Tlingit, we are almost overwhelmed by the lack of resemblance to animals.

To assist in the interpretation of early art, we have the advantage of an accumulation of fables attributed to Aesop, Persian fables from the Baharistan, Hindu fables from the Panchatantra and miscellaneous fables from China, Russia, Italy and numerous other countries. The legends of many of the American Indians have been collected and published in various reports. The artist is certainly indebted to the untiring efforts of the ethnologist, who is doing much to gather and translate these legends before they are lost forever.

Some of the earliest accounts of insects are found in the ancient Hebrew writings ultimately translated into the most outstanding example of English literature. The Septuagint version chronicles events that happened as early as 1500 B.C. Numerous insects[1] are mentioned; notably, ants, bees, beetles, fleas, flies, gnats, grasshoppers, hornets, lice, locusts, moths and palmer-worms. The ant is extolled for its provident habits, its industry and its foresight. The gnat, a variety of the mosquito, occurs only in Matthew, 23: 24, "Ye blind guides: which strain at a gnat, and swallow a camel." In Job 4: 19, reference is made to the fragile cocoon of the moth. The beetle, cankerworm and palmer-worm were probably the locust, which, by the way, was represented in the original by numerous names to refer to the various stages of development of this insect. By the command of Moses and the Lord, Aaron stretched forth his hand and smote the dust with his rod and straightway it became lice in man and beast. The Lord likewise brought the pestilent, buzzing swarms of flies and hordes of locusts upon Pharaoh as imprecations.

Classical literature abounds with ref-

[1] J. G. Wood, "Bible Animals," 1876.



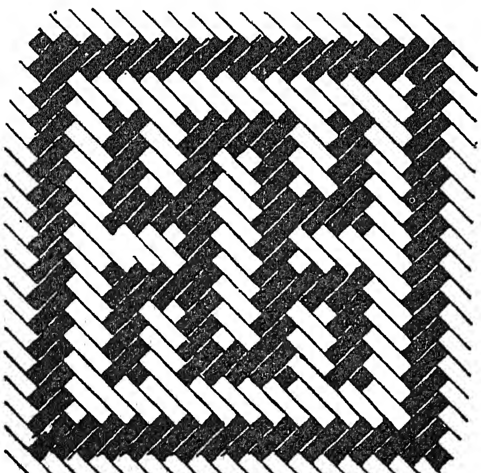
Butterfly motives from Pueblo pottery. (After Cushing.)

erences to insects. At best we can mention only a few. The ancient poets and philosophers frequently alluded to them. Virgil, in Book IV, the Georgics, gives an interesting and detailed account of the honey-bee, a portion of which we quote.

The bees have common cities of their own,
And common sons: beneath one law they live,
And with one common stock their traffic drive.
Each has a certain home, a several stall
All is the state's; the state provides all.

. . . .

Their toll is common, common is their sleep:
They shake their wings when morn begins to peep;
Rush through the city gates without delay;
Nor ends the work, but with declining day.



Beetle motif from a basket of the Guiana Indians. (After Roth.)

Homer's Iliad, because of its bellicose nature, speaks more frequently of panthers, lions and boars, although insects are occasionally mentioned. In Book 2, reference is made to "The numerous swarms of clustering flies."

Aristotle's "Historia Animalium" is replete with accounts of the habits of various insects. He recognized the three castes of bees—female, worker and drone—and wrote many interesting things concerning them. Pliny likewise deals with bees in some detail, stating that they occupy the first rank among insects and were created for man. Aristophanes refers to the pestiferous bedbug. "The Wasps" is a comedy on the Athenian love of litigation. Xenarchus speaks boldly of the female sex.

Happy the cicadas' lives
For they all have voiceless wives.

The Japanese have many interesting legends concerning insects. The butterfly is frequently regarded as a symbol of immortality because it changes from a homely caterpillar to a beautiful winged insect. In "The White Butterfly" an old man, on the point of death, was visited by a white butterfly that fluttered about the room and lit upon his shoulder. It flew to a nearby cemetery and lingered for a short time over a woman's tomb, then mysteriously disappeared. The woman was the man's sweetheart, and to her he had been faithful. As he could no longer go to visit her, she came to him in the form of a butterfly.

Hsiako-skik, according to tradition, dreamed he was a butterfly, and upon

waking the dream was so real that he could not tell whether he was a man who dreamed he was a butterfly or a butterfly who dreamed he was a man.

The dragon-fly, praying mantid, cricket, locust and firefly were special favorites of the orientals. The Japanese placed crickets in cages and admired them for their music. The Chinese immortalized the firefly in verse.

Rain cannot quench their lantern's light
Wind make it shine more brightly bright
O why not fly to heaven afar
And twinkle near to the moon-a-star?

More recent writers have been moved by the ways, music or charm of insects.

The wrech of God hym smoat so cruelly
That thrugh body wikked wormes crepte.
—*Chaucer*

Milton frequently refers to insects. His malediction in "Paradise Lost" reminds us of the plagues of Egypt:

Frogs, lice, flies must all his palace fill
With loathed intrustion, and fill all the land.

We can not omit Robert Burns's "To a Louse," inspired on seeing one on a lady's bonnet at church, or Charles Dickens's "Cricket on the Hearth," a story of simple life inspired by the rhythm of the cricket's chirp.

The American Indians also had their songs, but translations are often crude and impress us by their constant repetition. The feast song of the Kwakiutl is characteristic of much of our Indian poetry.

I am chief, I am chief, I am your chief,
Yours, who you are flying about.
I am too great to be bitten by those little flies that are flying about.
I am too great to be desired as food by those little horseflies that are flying about.
I am too great to be bitten by those little mosquitoes that are flying about.

The prayer song of the Navaho is equally as monotonous.

On the trail marked with pollen may I walk
With grasshoppers about my feet may I walk
With dew about my feet may I walk.

Into music also crept the insect note. A few composers have taken motives from the insects. The best known is "The Flight of the Bumblebee," by Nicolas Rimsky-Korsakov. The high-pitched violin gives a realistic representation of the hum of the bee. "Bombola," by Henry Kimball Hadley, also suggests the bee. Antol Liadov, a pupil of Rimsky-Korsakov, adds to our reper-

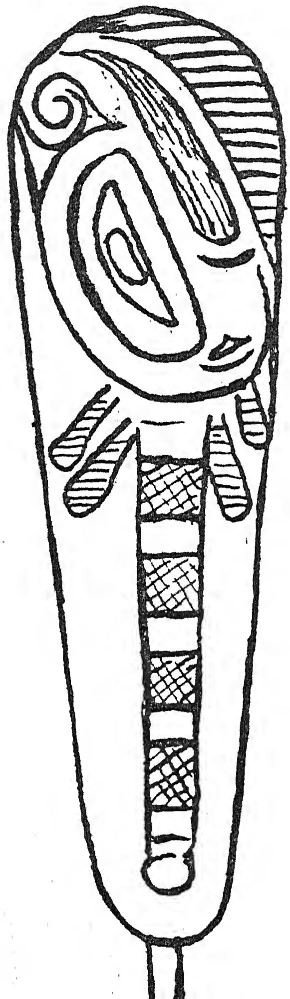
GRASSHOPPER MOTIF FROM MIMBRES POTTERY. (RESTORED AFTER COSGROVE.)

toire "The Dance of the Mosquito." Another dipteran selection is "The Minuet of a Fly," by Alphonse Czibulka. The Coleoptera have also been remembered especially by Gustav Holtz in "The Beetle's Dance." Edward Greig and Frédéric François Chopin have taken motives from the butterfly, calling their selections "Papillion." "The Glow Worm," a popular piece of yesterday, is worth mention.

The larger animals attracted man's attention long before insects and other arthropods were copied in art. As a matter of fact, the etchings and paintings of the grottos of La Grieze, La Mouth, Niaux, Tortosilla and Altmira, which

reveal the earliest traces of art, show chiefly mammoths, bison and reindeer. The salmon is represented on an engraved antler from the Lorthet cave in the Pyrenees, but the insect is entirely absent from these early attempts at art.

The cylindrical and probably the button-like seals of Babylonia and Assyria, which were carved from chalcedony, carnelian, rock crystal and other hard stones, reveal some of the first representations of insect intaglios.



BERRY SPOON WITH ENGRAVING OF DRAGON-FLY, HAIDA. (AFTER BOAS.)

In Egypt, the scarab was the most popular insect. The Egyptians were familiar with the habits of this beetle and selected it as a symbol of their god Khepera. It signifies "He who turns" or "Rolls," referring to the dung-rolling habits of the beetle. It was supposed to represent a type of human soul emerging from the mummy case and was always figured on the mummy case. The scarab did not come into general use until the eleventh dynasty, about 2500 B.C. They were carved from various materials; the poor used clay or stone, while those who could afford wore scarabs of jasper, lapis lazuli or even gold. Although the scarab originated in Egypt, it was later adopted by other countries, especially Crete, Syria, Italy, Sardinia, and was particularly common in Greece and Etruria. Petri[2] compares the scarab with the Christian cross. It is interesting to note that Murray-Aynsley likens the sutures of the scarab to the tau cross.

The scarab was frequently used as a motif in architecture. We find it on the lintel of the doorway of the temple of Dendur, built about the time of Augustus. The vulture, Nekhabit, is carved, with outstretched wings, below the scarab. These two motives, because of their similarity, are sometimes confused. On the sides of the doorway are the caduceus, a symbol frequently used in the medical profession. The scarab occurs elsewhere, notably the tomb of Gemneka at Sakkara, built during the reign of Teta or Pepi, and on the famous tomb of Tutankhamen.

Other arthropods, chiefly the fly, bee, locust, spider and scorpion, were used occasionally in Egyptian art. We figure a string of gold beads from the Ur, dating about 2300 B.C., composed of eight flies separated by round beads. Butterflies occur on the jewelry of the Princess Khnumet, who lived during the reign of Amenemhet. Other butterfly examples

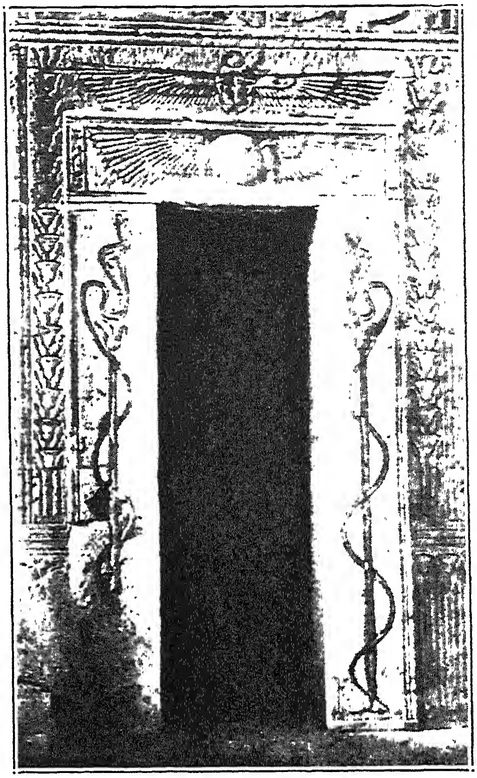
[2] W. M. F. Petri, "Amulets," London, 1914, "Seals and Cylinders," London, 1917.

may be found in architecture, especially on the decoration of the ceiling of the palace of Amenophis III at Thebes.

In Greece, insects take a prominent place on coins, especially those of Ephesus. A silver tetradrachm, in use between 400 and 336 B.C., bears a bee and the letters Ε Φ (of the Ephesians) and, on the reverse, the fore parts of a stag and a date-palm-tree with the letters ΑΡΙΣΤΟΔΗΜΟΣ (Aristodemus). Both bee and stag are symbols of Diana, an Asiatic goddess identified by the Greeks with Artemis. A tridrachm has a bee and the letters Ε Φ, as above, but in addition the signature of the magistrate ΓΕ: the reverse bears the infant Hercules kneeling on the left knee and strangling two serpents, also the letters ΣγΝ. The date of this coin is 394–295 B.C. A Rhodian tertadrachm dated 394–295 B.C. has a bee and the letters Ε Φ and on the reverse the fore parts of a stag and a palm-tree, with the letters ΠΑΓΚΡΑΤΙΔΗΣ. Another coin of the fifth century is wedge-shaped, very thick and irregular in shape, with a bee on one side and no apparent markings on the reverse.

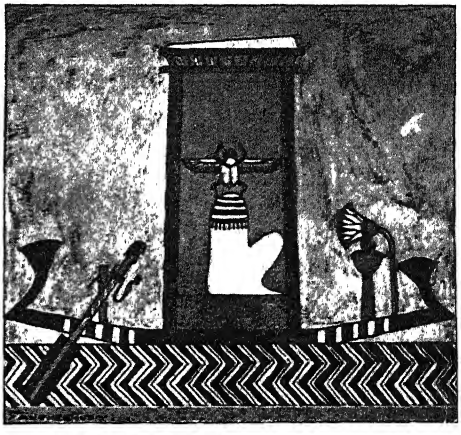
Japanese art exhibits an abundance of beautiful inros, netsukes and exquisite carvings of ivory, jade, rock-crystal, wood and metal. There is scarcely a subject which has not been used. The object is generally fashioned to illustrate some mythological figure. Most museums of oriental art feature great collections of these beautiful objects. I have seen a netsuke in the form of a worm-eaten chestnut and an inro with a cicada on one side and two dragon-flies on the reverse. Brockhaus, an authority on netsukes, describes many fine specimens.

The sword guards of the Japanese show exquisite carving, remarkable inlaying and unique finishes or patinas. They represent the most refined and elaborate technique found anywhere in the realm of art. Iron, copper, tin, zinc



A DOORWAY IN THE TEMPLE OF DENDUR.

THE SCARAB OCCURS ABOVE, THE VULTURE BELOW, ON THE LINTEL. THE CADUCEUS IS CARVED ON EACH SIDE OF THE DOORWAY. (AFTER MASPERO.)



KNOPRI THE SCARAB GOD SEATED ON HIS BARK. (AFTER MASPERO.)

Upper: A TYPICAL COIN OF EPHESUS (MUSEUM FINE ARTS, BOSTON). *Lower:* A STRING OF GOLD BEADS WITH FLY AMULETS FROM THE UR (UNIVERSITY MUSEUM).

and numerous alloys, such as shakudō, sentoku and shibuichi, known only to the Japanese, have been used. Examples are numerous in oriental collections. They take their names from the maker thus: Fukwansai, an iron tsuba, with a spider web in relief and a large spider inlaid in copper; Hidenaga, a small iron tsuba, with two dragon-flies inlaid in gold near the raised edge.

The South American Indians used insects and spiders frequently to adorn their pottery, baskets and other crafts. They are well represented on the baskets of the Guiana Indians. Roth[3] has described the weaving and intricate designs of their baskets. These are especially interesting because there is considerable limitation of the pattern that can be employed. The design must be indicated by short lines and is of necessity conventional or represented by geometric figures. It is surprising the number of natural elements that have been used, such as the deer and the monkey. Among the arthropods the beetle, the grub and the scorpion have been copied.

In Mayan art, we find that the bee, dragon-fly, scorpion and spider are especially common and are generally carved in stone. Tozzer and Allen[4] have figured and described many of these.

Insects have been used frequently by the North American Indians. The butterfly motif of the Hopi is especially fine. The body is usually represented as a triangle. The wings are generally folded and often have marks characteristic of certain genera. They might easily be mistaken for birds if it was not for the jointed antennae. Moths are frequently

GOLD PLATES FROM GREECE WITH BUTTERFLY AND SPIDER MOTIVES. THESE WERE PLACED OVER THE FACES OF CORPSES. (AFTER WALTERS.)

[3] W. E. Roth, Thirty-eighth Report, Bureau of American Ethnology, 1916–1917.

[4] A. M. Tozzer and G. M. Allen, Peabody Museum, IV, 13, 1910.

represented by more highly conventional figures. The Arapaho, Kwakiutl and Salish often use geometric figures to represent insects. The spider, in Hopi mythology, is associated with the sun and is symbolic of their earth goddess. It is also one of the symbols of the Hoga of the Osage tribe.

The insect has nowhere been so beautifully and so abundantly copied as by the aborigines of southwestern New Mexico. Cosgrove[5] figures many excellent pottery bowls from the Swartz Ruins. Most of these are decorated on the inside with patterns of black and white and insects take a prominent place. Grasshoppers, butterflies, dragon-flies, centipedes, spiders and scorpions have been used. The designs are highly conventional and are usually enclosed by circles or bands of geometric figures. The majority of these bowls were buried with the dead, and many of them are imperfect.

There is scarcely a branch of art that does not exhibit the insect in some form. We find them as marks on china and pewter, as printers' marks, as water-marks, especially on stamps, also in heraldry. An outstanding example of the latter is the shield of Napoleon, which bears three bees.

We might continue to enumerate examples, but we have gone far enough to illustrate that insects are commonly used in art. The abundance of insects, both from the standpoint of the number of described species and the number of individuals, furnished ample subjects for a variety of motives. The diversity of the habits of insects, their association with water, certain plants, animals or even man, has led to frequent use in folk-lore.

[5] H. S. and C. B. Cosgrove, Peabody Museum, V, 1, 1932.

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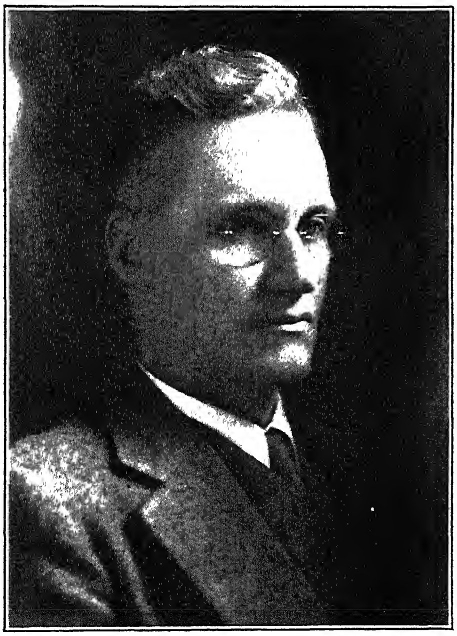
THE PROGRESS OF SCIENCE

THE PHILADELPHIA AFTERMATH OF THE ATLANTIC CITY MEETINGS

ON Saturday, January 2, 1937, members of the American Association for the Advancement of Science and its Affiliated and Associated Societies are invited to visit several of the scientific institutions of Philadelphia. As this will be on the way home for most of those attending the meetings in Atlantic City it is hoped that they will take advantage of this opportunity to see some of the oldest and most renowned scientific societies and institutions in this country. Visitors will be the guests of the American Philosophical Society, the Academy of Natural Sciences and the Franklin Institute.

The principal host on this occasion will be the American Philosophical Society, which is the oldest learned society in America. It developed from a small club, the Junto, started by Franklin in 1727. In 1743 he proposed the organization of a more general "Society for Promoting Useful Knowledge among the British Plantations in America," along the lines of the Royal Society of London, which had been founded in 1660. This new society, which included several members of the Junto, was to be composed of "virtuosi or ingenious men," residing in the several colonies and was to be held in Philadelphia as the most central place, and to be called The American Philosophical Society.

For more than twenty years another society with similar aims but different social and political ideals existed in Philadelphia, but in 1769 the two were united under the title "The American Philosophical Society held at Philadelphia for Promoting Useful Knowledge."



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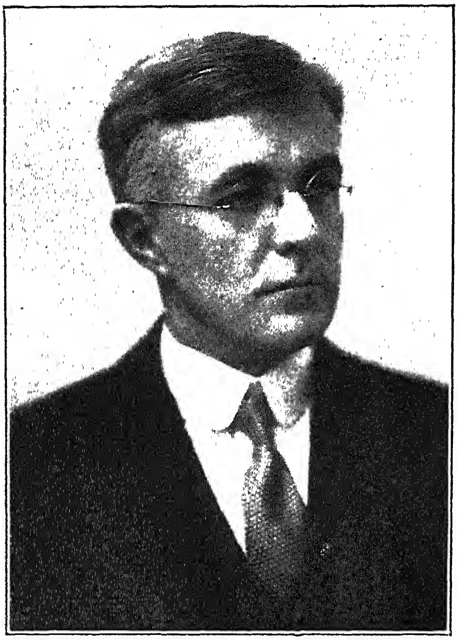


DR. IRVING LANGMUIR
ASSOCIATE DIRECTOR, RESEARCH LABORATORY, GENERAL ELECTRIC COMPANY; CHAIRMAN OF THE SECTION OF CHEMISTRY.

DR. FREDERICK H. SEARES
ASSISTANT DIRECTOR, MOUNT WILSON OBSERVATORY; CHAIRMAN OF THE SECTION OF ASTRONOMY.

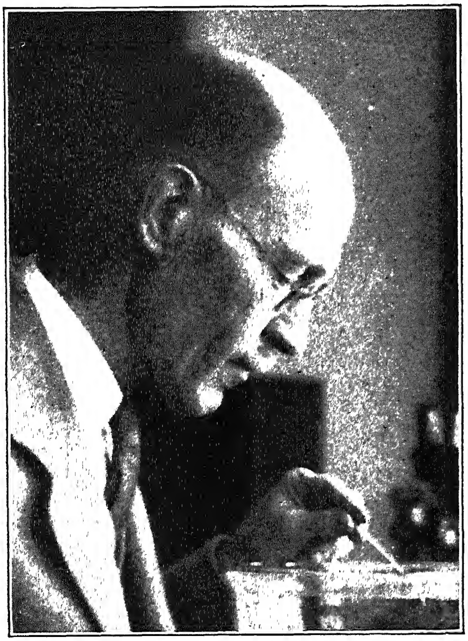
After this union Franklin served as president until his death in 1790; his successor was David Rittenhouse, and the third president was Thomas Jefferson, who held that office for eighteen years, during which time he contributed papers to the early volumes of the *Transactions* of the society and served for eight years as President of the United States. Twelve other Presidents have been members of the society, fifteen were signers of the Declaration of Independence, eighteen

DR. GEORGE R. MANSFIELD
GEOLOGIST, U. S. GEOLOGICAL SURVEY, CHAIRMAN OF THE SECTION OF GEOLOGY AND GEOGRAPHY.

were framers of the Constitution of the United States, thirteen have been Justices of the Supreme Court. In addition to these national figures, the society has included in its membership a large number of the leading scientists and scholars of this and other lands. At present its membership is limited to five hundred residents of the United States and sixty foreign members who are classified as follows: Class I, Mathematical and Physical Sciences; Class II, Geological and Biological Sciences; Class III,

Social Sciences; Class IV, Humanities. It is thus a learned society, limited in membership but general in scope. Its principal activities consist in holding stated meetings for the presentation of original work, the publication of research in various fields of learning, the support of research by grants-in-aid, and the maintenance of a scientific and historical library.

For 150 years the society has met in its own building on Independence Square,



DR. ROSS G. HARRISON
PROFESSOR OF BIOLOGY, YALE UNIVERSITY; CHAIRMAN OF THE SECTION OF ZOOLOGICAL SCIENCES.

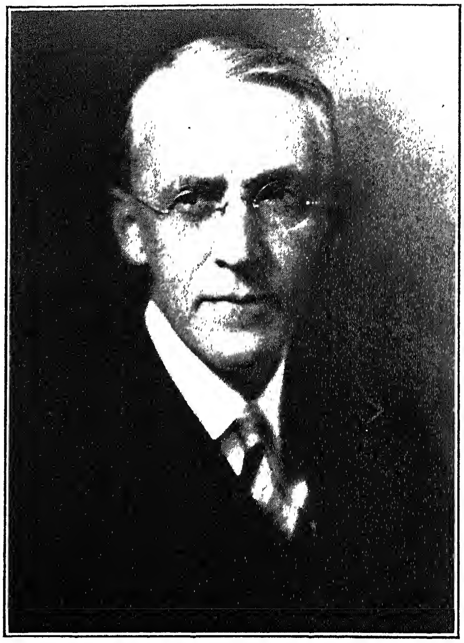
which is one of the shrines of science and learning in America, as Independence Hall is a shrine of patriotism. Here are found priceless relics of our early history—the original Charter of Privileges granted by William Penn to the colonists of Pennsylvania; the surveying instrument used in laying out the City of Philadelphia; the largest collection of Frankliniana in existence, including more than seventy bound volumes of his papers and letters, his numerous publications, many of his personal be-

DR. JESSE MORE GREENMAN
PROFESSOR OF BOTANY, WASHINGTON UNIVERSITY; CHAIRMAN OF THE SECTION OF BOTANICAL SCIENCES.

DR. RALPH LINTON
PROFESSOR OF ANTHROPOLOGY, UNIVERSITY OF WISCONSIN; CHAIRMAN OF THE SECTION OF ANTHROPOLOGY.

DR. EDWARD S. ROBINSON

PROFESSOR OF PSYCHOLOGY, YALE UNIVERSITY; CHAIRMAN OF THE SECTION OF PSYCHOLOGY.



DR. E. H. WILKINS

PRESIDENT, OBERLIN COLLEGE; CHAIRMAN OF THE SECTION OF HISTORICAL AND PHILOLOGICAL SCIENCES.

DR. HAROLD G. MOULTON

PRESIDENT, BROOKINGS INSTITUTION; CHAIRMAN OF THE SECTION OF SOCIAL AND ECONOMIC SCIENCES.

DR. W. E. WICKENDEN

PRESIDENT, CASE SCHOOL OF APPLIED SCIENCE; CHAIRMAN OF THE SECTION OF ENGINEERING.

DR. JOSEPH T. WEARN
PROFESSOR OF MEDICINE, WESTERN RESERVE UNIVERSITY; CHAIRMAN OF THE SECTION OF MEDICAL SCIENCES.

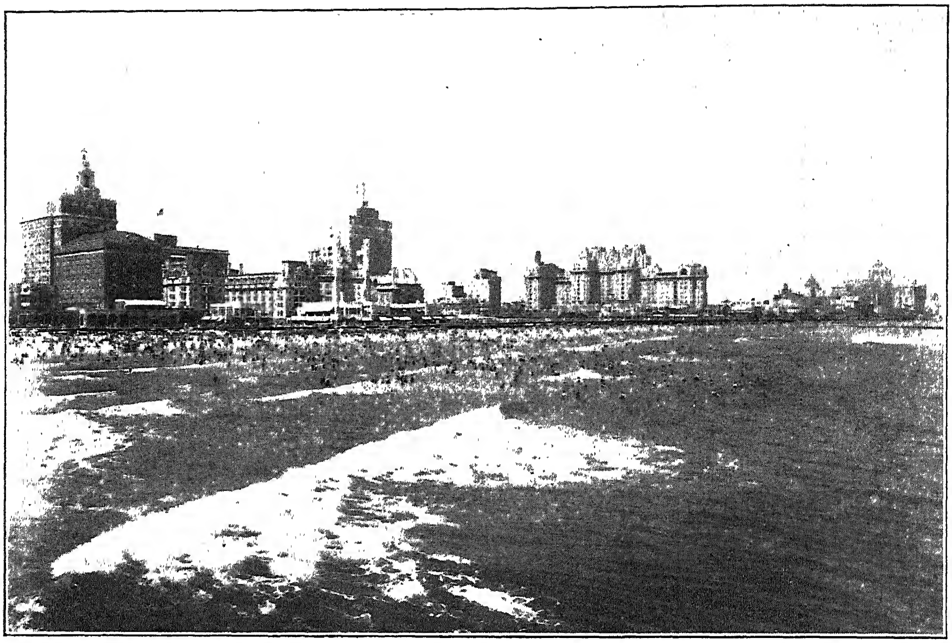
DR. P. E. BROWN
PROFESSOR OF SOILS, IOWA STATE COLLEGE; CHAIRMAN OF THE SECTION OF AGRICULTURE.

longings, instruments with which he conducted his early experiments on electricity, as well as models of his numerous inventions; the telescopes purchased by the society and the clock made and used by David Rittenhouse in the observations of the transit of Venus across the sun in 1769; a model of a steamboat invented by John Fitch in 1785, etc. Here are also many manuscript letters and papers of Washington, Jefferson, Madison, Monroe and other founders of the nation; here is the first draft of the Declaration

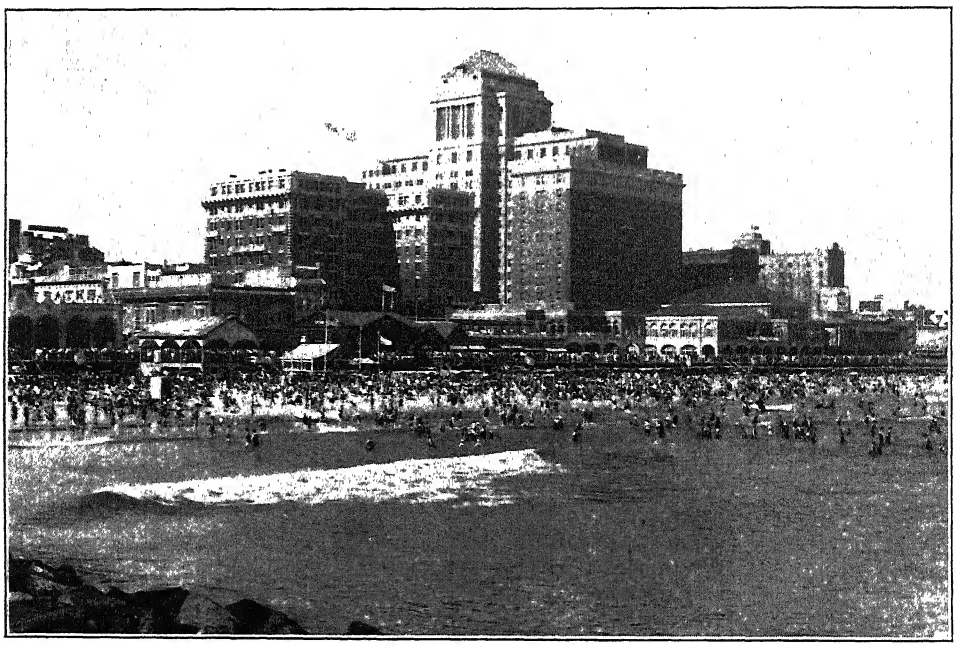
DR. E. S. EVENDEN
PROFESSOR OF EDUCATION, TEACHERS COLLEGE, COLUMBIA UNIVERSITY; CHAIRMAN OF THE SECTION OF EDUCATION.

of Independence in the handwriting of Jefferson and the desk-chair in which he is said to have written it; here are the manuscript journals of Lewis and Clark on their exploring expedition across the continent; here are many thousands of volumes of the publications of learned societies, as well as many other objects of interest.

The Academy of Natural Sciences is celebrating this year its 125th anniversary; for many years it has been a center



THE HOTELS ALONG THE BOARDWALK AT ATLANTIC CITY



THE HOTEL HEADQUARTERS OF THE AMERICAN ASSOCIATION
THE CHALFONTE-HADDON HALL HOTEL.

of biological and geological research. Among its early officers, members and workers may be mentioned Audubon, Wilson and Cassin; Say, Lea and Tryon; Le Conte, Horn and McCook; Leidy, Ryder and Cope. From its foundation to the present it has been the principal contributor to zoological taxonomy in America, and its collection of type specimens in certain fields is unexcelled. Recently it has undertaken the development of a great natural history museum for the general public, as well as for the specialist. Its library of natural history is one of the best in this country and its portraits and memorabilia of the greatest naturalists are of especial interest to all biologists and geologists. For more than sixty years it has occupied its present location at 19th Street and the Parkway, although its building has been greatly enlarged and improved in recent years.

The Franklin Institute is another Philadelphia organization which is the lengthening shadow of a great man. Founded in 1824 for the promotion of the mechanic arts, The Franklin Institute from its inception awarded medals to encourage the application of scientific principles to industry, it published a *Journal* which has since become international in character, it conducted courses of lectures of a scientific nature and it started a library which is known to-day as one of the best technical collections in the country. Within the last twenty years it has added two research laboratories to its original building—one, known as the Bartol Research Foundation, is devoted to research in pure science, and the other, the Biochemical Foundation, studies researches in chemistry, with special emphasis on cancer research.

AMERICAN PHILOSOPHICAL SOCIETY
MEMBERS' MEETING ROOM SINCE 1789.

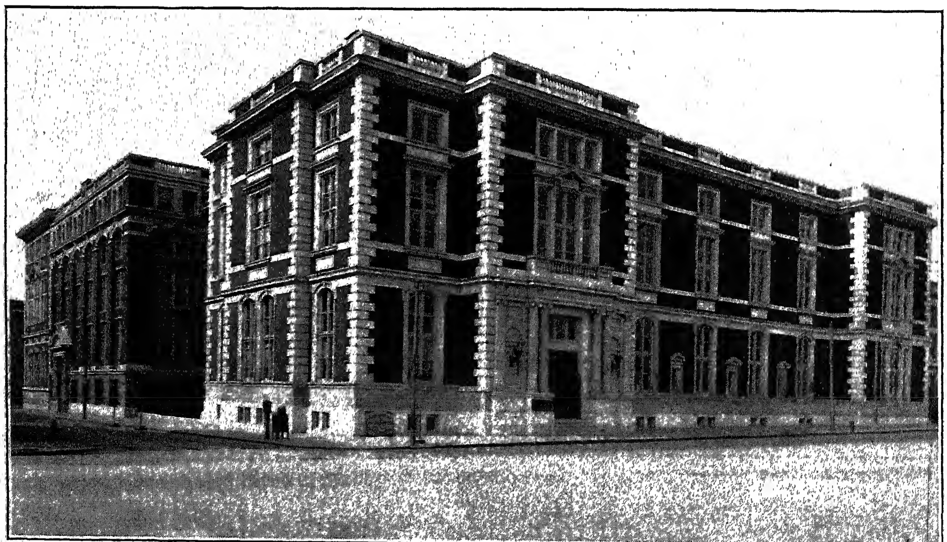
In 1930, in a public drive, five millions of dollars was raised with which to build a memorial to Benjamin Franklin and a new home for The Franklin Institute. This building now stands on the Parkway at Twentieth Street in Philadelphia, an edifice of great beauty, devoted to the teachings of science and the memory of America's great personage—Benjamin Franklin. It contains, besides its library and lecture hall, the Fels Planetarium and a great industrial and sci-

entific museum, in which the exhibits are self-operable. Franklin himself contributed to the building of this memorial when, in a codicil to his will, he gave £1,000 to the City of Philadelphia to be let out at interest to married artificers under the age of twenty-five years, evidently with the thought of their better training. In 1824, when the institute was chartered for the promotion of the mechanic arts, it conducted schools and had the first technical high school in the country. Because of this activity it was made the beneficiary under Franklin's will by the Board of Directors of City Trusts of the City of Philadelphia in 1907 when that body voted to give it $131,000, the sum then available from Franklin's legacy. This money was added to the building fund of the Institute and thus was used for the memorial on the Parkway in Philadelphia.

These three organizations—the American Philosophical Society, the Academy of Natural Sciences and the Franklin Institute—are to be hosts to members of the A. A. A. S. and the Affiliated and Associated Societies on January 2, but other institutions in the city will gladly welcome visitors on this occasion.

The train leaving Atlantic City at 8:25 in the morning reaches Camden at 9:35 and Market Street Wharf, Philadelphia, at 9:45. The Hall of the American Philosophical Society, 104 South Fifth Street, is only a few minutes walk from this wharf. A number of papers on "Viruses and Virus Diseases" by outstanding investigators in this field will be given in the Lecture Hall of the American Philosophical Society between 10 and 1 o'clock. Lunch will be served in the society's rooms for members and guests, and after lunch visitors may go to the Academy of Natural Sciences and the Franklin Institute where they will be received and shown around, or they may go to the Art Museum, the University of Pennsylvania, the University Museum, or other places of interest in Philadelphia. Those who prefer to go directly to the Academy or the Franklin Institute should continue on the bridge train to Broad Street Station, which is but a short distance from those institutions.

EDWIN G. CONKLIN



ACADEMY OF NATURAL SCIENCES OF PHILADELPHIA

THE BENJAMIN FRANKLIN MEMORIAL AND THE FRANKLIN INSTITUTE

THE CANCER SYMPOSIUM AT ATLANTIC CITY

THE Section on Medical Sciences of the American Association for the Advancement of Science has arranged for the Christmas meetings at Atlantic City a symposium on cancer consisting of a series of seven sessions to be held from Tuesday to Friday, December 29 to January 1, inclusive. The first session, which will be held on Tuesday morning, will be devoted to questions concerning radiation, while the afternoon will be devoted to various aspects of the relationship of hereditary and constitutional factors to the occurrence of tumorous growth. The two sessions on Wednesday will be concerned with the induction, stimulation and inhibition of tumors. This will involve a consideration of the carcinogenic substances, the relationship of the sex hormones and the significance of viruses and of inhibitory substances to the etiology and development of tumors. On Thursday morning tissue culture work in connection with cancer will be discussed and the metabolism of cancerous tissue will be considered. In addition to these sessions, there will be two general lectures, one on Thursday afternoon and one on Friday, which will take up certain more general aspects of the cancer problem. The section is anxious to make this as worth while a symposium as possible and has brought together the leaders in the various fields. In so doing it hopes that it will call attention to the fundamental work that is going on in this country in the investigation of this serious problem and will afford an opportunity for an authoritative survey of the actual status of this field.

The two general papers will be given by Dr. C. C. Little, of the Roscoe B. Jackson Memorial Laboratory, and Dr. Walter Schiller, of the University of Vienna. Dr. Little will present a general lecture for not only Section N but for the entire association at 4:30 on Thursday and his subject will be on the social significance of cancer. Dr. Schiller will lecture at 4:30 on Friday afternoon on changes

and modifications in the conception of carcinoma. It may also be mentioned that the American Society for the Control of Cancer has been invited by the association to hold an exhibit on various aspects of the social control of cancer.

In addition to the cancer symposium the Medical Sciences Section is planning to hold a joint session with the pharmacy subsection on Monday afternoon, and the general session for the presentation of general papers will be held on Friday morning.

The association has been invited to hold the last day of the meetings on Saturday, January 2, at Philadelphia. Accordingly, the Medical Sciences Section plans to hold one session on Saturday morning at 10:30 at the Philosophical Society in Philadelphia and has invited Dr. Wendell Stanley, of the Rockefeller Institute, Princeton, N. J., to give a lecture regarding the interesting and important work that he has been doing on the tobacco mosaic virus which he has succeeded in crystallizing. The afternoon will be devoted to visiting the various medical scientific laboratories in Philadelphia.

VINCENT DU VIGNEAUD,
Secretary of Section N

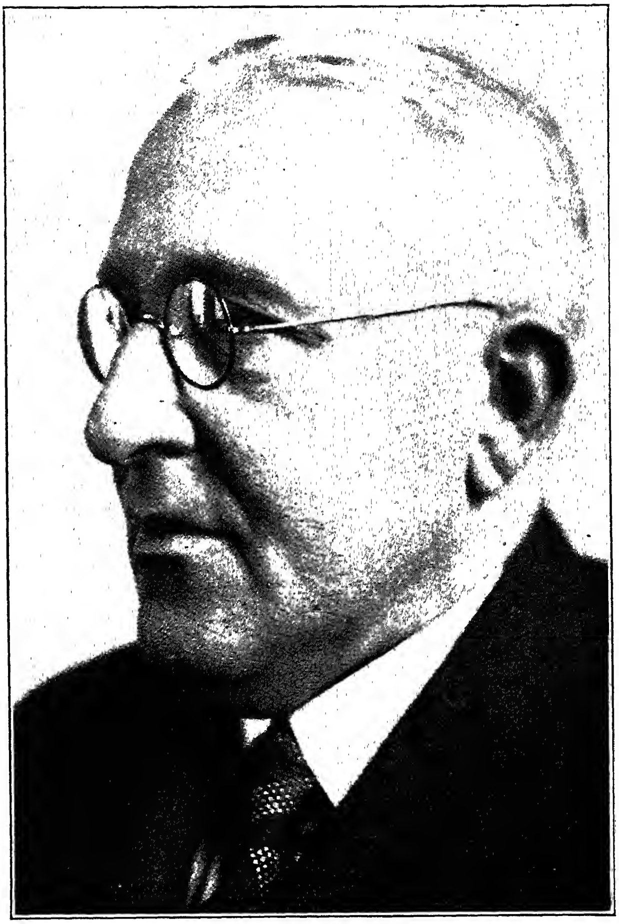
MEDICAL SCHOOL,
GEORGE WASHINGTON UNIVERSITY

AWARD OF THE NOBEL PRIZE IN PHYSICS TO VICTOR F. HESS AND CARL D. ANDERSON

EVERY informed physicist will acclaim the award of the Nobel Prize in physics to Victor F. Hess; for after a decision had been made that the first significant work in the field of cosmic rays was to be honored by a Nobel Prize there was certainly no living person who could for a moment be considered for that award except Dr. Hess. The Swiss, Gockel; the Austrian, Hess; and the German, Kolhörster, were undoubtedly the three persons who opened up this field. Their early work was done from 1910 to 1914, and no other particularly important work of this sort appeared until about a decade later, when the modern era of cosmic ray research was ushered in. Gockel died about a decade ago, and Kolhörster's important work definitely followed that of Hess. I can not tell the story of that early work more accurately or more interestingly than through the following quotations from "Electrons (+ and −), Protons, Photons, Neutrons, and Cosmic Rays," published in 1935:[1]

"Up to 1910 not a trace of evidence had appeared for the existence of any rays of a penetrating power greater than that of the gamma rays of radium and thorium. Indeed, all the work that had been done prior to 1910, even on rays capable of discharging electroscopes through metal walls centimeters or even inches thick, was interpreted in terms of such earth rays, or of the radiations given off by the radioactive emanations getting from the earth into the lower atmosphere, and these are, in fact, responsible for much the greater part of the observed electroscope-discharging effects found on the earth's surface. Also, prior to 1910, not a trace of evidence had appeared that penetrating rays entered the earth from outside. Such a hypothesis had not even been seriously proposed. Apart from a passing suggestion of Richardson's in 1906 that electroscope-discharge effects observed at the earth's surface might possibly have something to do with solar influences—a suggestion quickly negatived by the fact that these effects are as strong in night time as in daytime—I can find no record of the existence anywhere up to 1910 of any ideas even remotely related to those that are now associated with the term "cosmic rays." Indeed, in 1909 all the work that had appeared in this field up to that date was

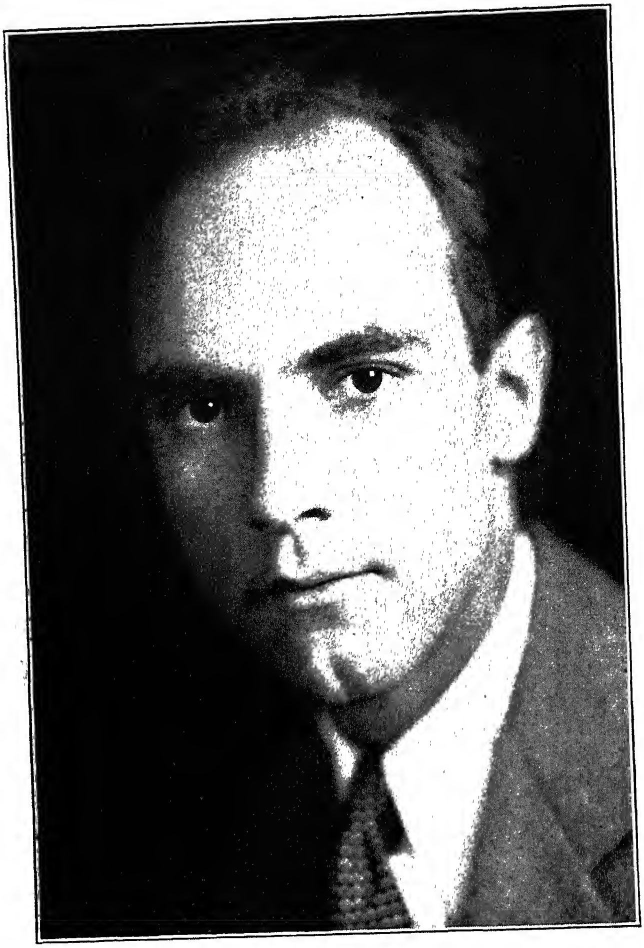
[1] University of Chicago Press.



PROFESSOR VICTOR F. HESS
PROFESSOR OF PHYSICS, UNIVERSITY OF INNSBRUCK.

reviewed by Kurz and careful consideration given to each one of the only three possible origins of the observed electroscope-discharging effects, namely (1) the earth, (2) the atmosphere, and (3) the regions beyond the atmosphere. *The last two were definitely discarded* and the conclusion drawn that there was not the slightest evidence for the existence of any penetrating rays other than those produced by radioactive substances in the earth—this with full knowledge, too, dwelt upon at length in this article, that half a mile of the earth's atmosphere was sufficient to absorb all such radioactive radiations.

"When, therefore, in 1910, the Swiss Gockel took an electroscope three different times in a balloon to heights that reached 4,500 meters and found that *its rate of discharge was there even higher than on the earth, he had discovered something new and important,* namely, that although there are penetrating rays that do originate in the earth and are indeed abundantly given off from practically all kinds of rocks and soils in the earth's crust, as Kurz and the other workers prior to 1910 had rightly concluded, yet *there must be other rays abundant at high altitudes that come in from* above originating either (2) in the



DR. CARL D. ANDERSON
ASSISTANT PROFESSOR OF PHYSICS, THE CALIFORNIA INSTITUTE OF TECHNOLOGY.

remoter regions of the atmosphere or else (3) coming in from outer space. . . .

"The next year, 1911, Hess, after repeating and checking Gockel's experiments, extending them to 5,200 meters, and making them more quantitative, spoke in favor of a return to Kurz' hypothesis No. 3, although at the same time suggesting the possibility of No. 2. He also pointed out the important fact that these discharging effects were apparently as strong in night time as in daytime. In 1913 and 1914 Kolhörster carried observations essentially like those of Gockel and Hess to 9,000 meters, and in interpreting his observed twelve- or thirteen-fold increase in discharge rate at that height over that at sea level, favored hypothesis No. 3."

Dr. Hess has also been active in *recent* cosmic ray research, having contributed some of the most accurate work which has been thus far done in this field.

That every informed physicist will also acclaim the award of the Nobel Prize in physics to Carl D. Anderson is quite as certain as is the case of the award to Victor Hess, for Anderson's discovery of the free positive electron is certainly one of as fundamental and far-reaching a character as has been made for years.

Why it is fundamental, I have described in the before-mentioned book in the following words:

"Prior to the night of August 2, 1932, the fundamental building-stones of the physical world had been universally supposed to be simply protons and negative electrons. Out of these two primordial entities all of the ninety-two elements had been formed. The proton was itself the positive unit of charge, or the positive electron, exactly like the negative unit so far as charge alone was concerned, but by its very nature different from the negative unit in that it was always associated with a mass 1,834 times that of the rest-mass of the negative electron. Thus, we assumed an intrinsic difference between the natures of positive and negative electricity, and explained the fact that not only was the whole positive charge of an atom concentrated in its nucleus, but also practically the whole of its mass as well. To fit all this into the electro-magnetic theory of the origin of mass, most of us, in view of J. J. Thomson's famous equation for the mass of a spherical charge, namely $m = \frac{2^{e^2}}{3a}$, conceived the positive unit of charge as having a radius *a* only $\frac{1}{1834}$ of the radius of the negative unit, as this equation seemed to require.

"A cosmic-ray photograph taken in the Norman Bridge Laboratory on the afternoon of August 2, 1932, put a stop to our complacency with the foregoing picture. Carl D. Anderson had taken the photograph and developed the film. He at once realized its importance, and, with Seth Neddermeyer, spent the whole night trying in vain to see if there were not some way of looking at it that would save the old point of view. It could not be done! The photograph revealed indubitably the track of a *free positive electron* having precisely the properties of the free negative electron, save for the sign of its charge—not at all the properties of the proton. The name of the proton might still remain, but its character had changed, for it was no longer itself the ultimate positive entity. A cosmic ray had apparently picked off from it the disembodied positive unit of electrical charge, the identical twin of the free negative electron."

Dr. Anderson, too, though a very young man, has had other notable accomplishments in addition to the discovery of the positive electron. He is largely responsible for the initiation of the whole group of researches, now of world-wide extent, by which the energies of cosmic rays were made directly and accurately measurable. He and Neddermeyer were the first to prove by direct photography that a gamma ray photon impinging upon the nucleus of an atom produces through that impact a positive-negative electron pair. He and Neddermeyer have also been the first to demonstrate that pair formation is not the sole mechanism determining the absorption by the nucleus of an atom of high energy photons or electrons. But it is probable, in the case of both Hess and Anderson, that the Nobel Prize was specifically awarded because each was the earliest living experimenter in the initiation of a new field of physical knowledge, for, as indicated above, the Nobel Committee has in general tried to tie its award to some one particular notable accomplishment.

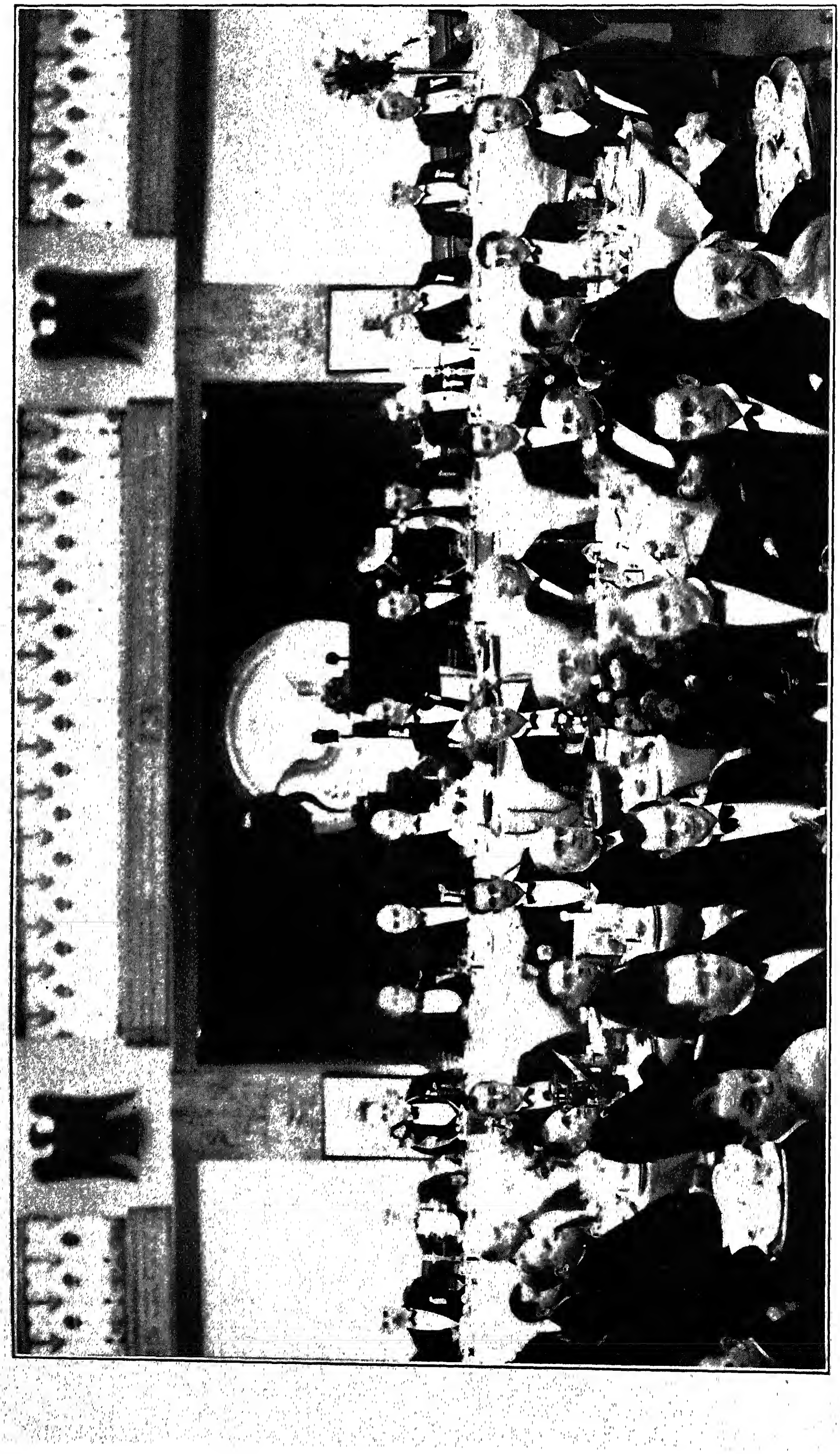
ROBERT A. MILLIKAN

CENTENNIAL CELEBRATION OF THE AMERICAN PATENT SYSTEM

A HUNDRED years ago the present American patent system came into existence, and during the century more than 2,000,000 patents were granted.

A one-day celebration of this anniversary was held on November 23 in Washington under the auspices of a national committee headed by Dr. Charles F. Kettering.

An honor roll of 12 of the greatest de-



BANQUET OF THE CENTENNIAL CELEBRATION OF THE AMERICAN PATENT SYSTEM IN WASHINGTON

Presiding at the center of the speakers' table is Dr. Charles F. Kettering, Vice-President of the General Motors Corporation and Chairman of the National Committee; on his right is Honorable Daniel C. Roper, Secretary of Commerce; at his left is Conway P. Coe, United States Commissioner of Patents. At the table below the speakers' table it was planned to place the twenty most distinguished American inventors who were able to be present.

ceased American inventors, a new type of scientific demonstration which brought the techniques of the stage, radio and screen to the aid of science in describing new discoveries, and a banquet consisting entirely of patent foods, for which the guests received licenses instead of tickets were the highlights of the program.

The morning sessions were held in the building of the National Academy of Sciences and the National Research Council. Four speakers reviewed the past, the present and the future of the present patent system. Dr. Harrison E. Howe, editor of *Industrial and Engineering Chemistry,* discussed "Importance of Inventions to Civilization"; Honorable Thomas Ewing, New York City, "The American Patent System"; Dean Dexter S. Kimball, College of Engineering, Cornell University, "The Great Inventions of the Century"; Dr. Robert E. Wilson, vice-chairman, Pan American Petroleum and Transport Company, "Looking Toward the Future of Invention."

The "Research Parade," planned by Watson Davis, director of Science Service and chairman of the program committee of the Centennial, was presented in the afternoon. The newest developments of scientific research were demonstrated in quick-moving, dramatic fashion. Using the technique of the newsreels and radio an off-stage voice carried the continuity between the various demonstrations. The auditorium was darkened and spotlights focused attention on the quick-tempoed demonstration. Music was provided by the phonographic attachment of the world's most powerful 50-tube radio set. The program was a departure from the more orthodox type of science presentation.

New fields of research demonstrated included: Television's electron tube applied to the microscope; polarized light and polarizing material which prevents blinding headlight glare in night driving; supersonics, sounds beyond the limit of hearing; lignin, the enigma of the forest; super-hard glass and the production of glass textiles; the production of synthetic rubber-like materials having properties excelling those of natural rubber; the effectiveness of the body's glands as shown in animal experiments; solar power; new methods of electrical power transmission, and the testing of silk stockings by National Bureau of Standards scientists. To demonstrate how much clothing and adornment owe to research and science, the "Maid of Science" joined the Research Parade, modeling raiment that not even ruling queens could have had a few decades ago.

In the auditorium of the Department of Commerce there was dedicated a bust of Thomas Jefferson, who in the early days immediately after the founding of the United States was vitally interested in the patent situation and influenced greatly its subsequent development which led to the legislation in 1836 founding the present patent system.

Throughout the day in the auditorium of the Department of Labor there were shown a selected group of industrial motion pictures illustrating through the medium of sound motion pictures the steps in the production of the products of America's leading industries.

A special exhibit in the Rare Books Division of the Library of Congress showed seldom seen books and manuscripts pertinent to the Patent Centennial. Included in this material was a lecture given by Abraham Lincoln on "Science and Invention," which is not found among his published works; also a prediction made early in the nineteenth century by Oliver Evans—the first man to build a steam locomotive in America—on the future of railroad transportation; and a rare manuscript written by Charles Goodyear, the discoverer of the process for vulcanizing rubber, in which it predicted the future uses of rubber. Rubber money was among the uses for the then new material which the enthusiastic Goodyear envisioned in the 1840's.

The culmination of the Patent Centennial was the banquet at the Hotel May-

flower, which consisted entirely of patented foods. The guests at this dinner received tickets that were licenses, to eat the food prepared, from the companies holding the patents on the food products. From the lobster meat cocktails to the demi-tasse and patented cigars and cigarettes, the dinner exemplified the achievements of science and invention which have made it possible to prepare an entire meal without thought of season, distance and climate.

The dinner was accompanied by pageantry of past and future. A crystal-gazing ball of patented material was used for foretelling the progress to come, and out of the past by means of the phonograph of his own invention came the voice of Thomas Alva Edison. The contrast between the old and the new was exemplified also by the music at the banquet, provided by a melodeon, vintage 1840, and the newest type of patented Hammond electrical organ, which duplicates in tone and excels in volume the largest pipe organ.

The contrast between the past and the present was further demonstrated by the special display of the most modern lighting, installed in the ballroom where the dinner was held. At the beginning of the dinner the entire illumination was provided by candles as fitting for the era of 1836. Then as the toastmaster, Dr. Kettering, waved his hand through the beam of a photoelectric cell the intensity of the special illumination at the banquet was increased until its magnitude excelled that ever used within four walls. Swelling in volume, with the amazing display of lights, were tones of the electric organ until the sound intensity was just below the volume which the human ear can tolerate.

It is estimated by electrical engineers that the electric power required for the lighting demonstration was sufficient to supply the current requirements of the rest of the hotel with its electric motors, elevators, lighting and large air conditioning system.

In the broadcast program following the dinner, Commissioner of Patents Conway P. Coe read the honor roll of the 12 greatest deceased American inventors.

Using one of the two original Morse telegraph receivers loaned especially for the occasion by Cornell University, Dr. Kettering received in the banquet hall the original Morse message, "What Hath God Wrought," sent over its original route from Baltimore to Washington. Scene of the transmission in Baltimore was the old Baltimore & Ohio Station, which was used in the original demonstration of the great communications invention.

From high overhead in a modern transport airliner came a short wave broadcast honoring the inventors of the century.

Secretary of Commerce Daniel C. Roper discussed the highly important place of the present patent system in the material industrial progress of the nation.

The dinner and ceremonies were followed by a dance sponsored by the Patent Office Society; in other cities dinners and meetings of patent lawyers were held on the same evening.

WATSON DAVIS,
Director

SCIENCE SERVICE

THE SCIENTIFIC MONTHLY

FEBRUARY, 1937

VISITING VENEZUELA

By Dr. FRANK D. KERN

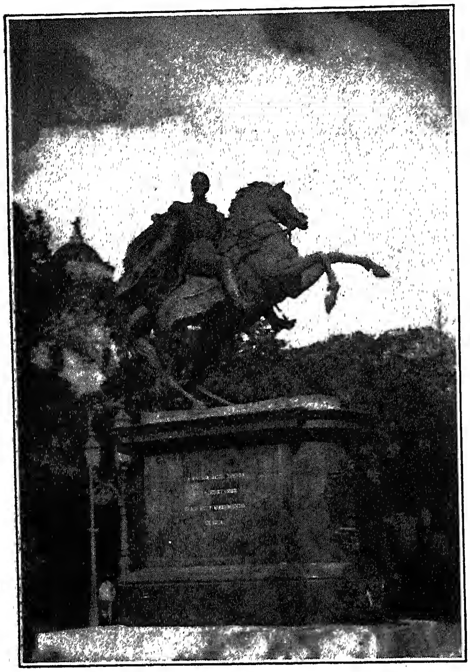
PROFESSOR OF BOTANY AND DEAN OF THE GRADUATE SCHOOL, THE PENNSYLVANIA STATE COLLEGE

HISTORICALLY Venezuela is an interesting place but not well known to most North Americans. Doubtless only the best students of American history remember that Columbus discovered the northeastern peninsula of Venezuela known as Paria on his third voyage in 1498. The next year what is now the whole Venezuelan coast was traversed by Ojeda and Amerigo Vespucci. Gradually conquered and settled by Spaniards, the region remained under their control for three hundred years. In the middle of the eighteenth century the colonists rose in revolt but were suppressed. Successful insurrections, fostered largely by Simon Bolivar, the great South American patriot and Liberator, brought about independence in the early part of the nineteenth century. Bolivar has been referred to frequently as the Washington of South America. As a consequence the name of Bolivar is encountered on every hand in Venezuela to-day. The Spanish pronunciation of his name is *Boleevar*. Every city and town has a "plaza Bolivar." In Caracas, the city of his birth, a monument has been raised in his memory; his remains were removed to Caracas in 1842; and the centenary of his birth was celebrated at Caracas in 1883. The unit of money in Venezuela is known as the "bolivar." The only other name at all comparable in the history and development of the country is that of General Juan Vicente Gomez, president for the past quarter century.

From 1819 to 1830 what is now Venezuela was a part of the republic of Colombia. Between 1830 and 1908 there were many civil wars and changes of constitution. Till 1864 Venezuela was made up of provinces, but since then has been a federal republic. It is perhaps not well known that the official designation is "The United States of Venezuela." There are twenty states and the federal district, in which the capital, Caracas, is located. In area Venezuela is just about equal to Texas and New Mexico combined, but its population of three million is less than three fourths that of those two states.

Since 1908, when General Gomez took over the reins of government, the tranquility of this nation has been outstanding in South American history, which has been marred by conspiracies, revolutions, dissentions, civil and international wars. Through all this Venezuela has enjoyed peace, quietude and progress under General Gomez. Cyrus Norman Clark, recently reviewing twenty-five years (1908–1934) under Gomez, wrote:

> While every other republic of the southern continent has been harassed by one or another form of political unrest, Venezuela alone has been undisturbed, free to pursue the development of her internal resources and foreign commerce. Her sister nations have struggled with

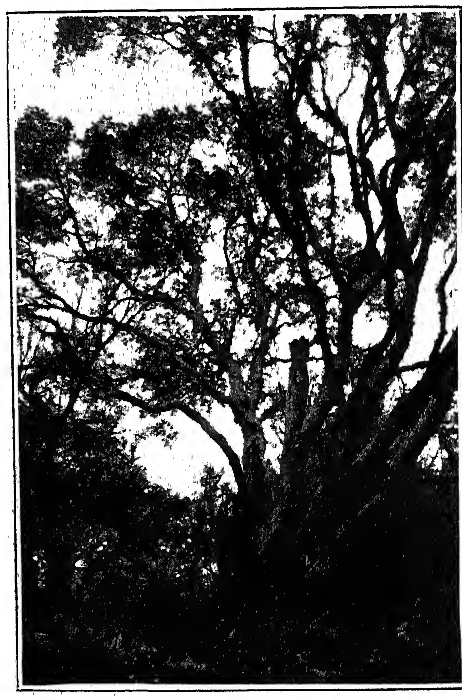


. STATUE OF SIMON BOLIVAR
IN THE CENTER OF PLAZA BOLIVAR, CARACAS.

unbalanced budgets or have defaulted, wholly or in part, in meeting their national indebtedness; while Venezuela has exhibited, year after year, an ample surplus of revenue, has liquidated her entire foreign debt, has reduced her internal debt to less than twenty-three million bolivars, and at the end of the last fiscal year possessed a treasury balance of nearly sixty-one million bolivars![1]

In 1908 Venezuela had a foreign trade of one hundred and thirty-seven million bolivars. By 1931 that trade had reached the sum of one thousand and twelve million. During the same period the national revenue increased from fifty million bolivars to one hundred and eighty-five million bolivars. Agriculture, manufacturing and natural resources have been developed. Coffee is the most important agricultural product. Cacao is next to coffee in importance. These two crops do not compete, as coffee is grown in the higher altitudes while cacao is grown in the lowlands. Considerable sugar-cane is grown, but much remains to be done to improve its quality and yield. Stock-raising has received attention in the great grassy plains of the Orinoco Valley, but has not begun to reach the proportions to which it could be developed. A government Agricultural Bank has been of great assistance to planters and breeders. The principal manufacturing enterprises are cotton textiles, sugar, paper and cement. Without doubt, the greatest single factor in the prosperity of Venezuela has been the discovery and development of the petroleum industry. The chief petroleum fields are in the Caribbean region around the shores of Lake Maracaibo. This great body of inland water is in reality

[1] Before the devaluation of the dollar, five bolivars equaled one dollar gold.



"COLORADITO," *POLYLEPIS SERICEA*

THE TREE THAT REACHES THE HIGHEST ALTITUDES IN THE ANDES OF MERIDA (THIS PICTURE TAKEN AT 3,500 METERS). THREE INTERESTING FUNGI WERE COLLECTED ON THIS SPECIMEN.

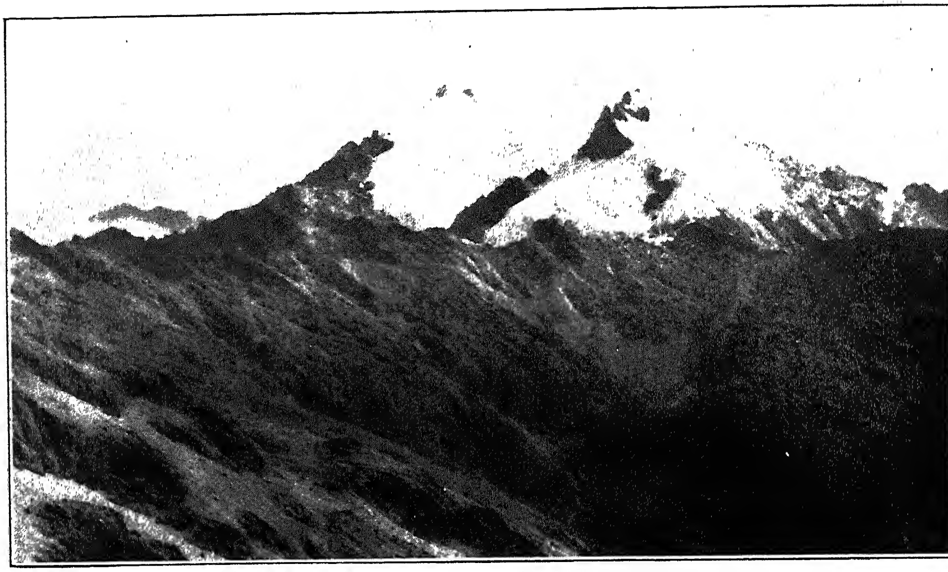
DIGGING OUT WILD POTATOES IN THE PARAMO ABOVE TIMOTES

CHANCELLOR CHARDON (CENTER) AND COMPANIONS. BOTH TUBERS AND SEEDS HAVE BEEN OBTAINED FOR BREEDING AND EXPERIMENTATION.

not a lake but an arm of the sea with a mouth which is a strait five miles wide. Its waters are always fresh, for they come down from the high Andes in such quantities that they push out the salt water from the sea. The oil fields are so close to the lake in some places that the derricks and tanks stand on piles a quarter of a mile from shore and can be reached only in launches.

The petroleum industry in Venezuela has been developed by foreign interests, principally British and American. Friends of the Venezuelan administration claim that the legal enactment under which foreign capital has operated there is a model for similar legislation. Whether that claim is justified may be difficult to determine, but it surely is true that mutually satisfactory arrangements have prevailed. The foreign companies have been dealt with liberally and at the same time the interests of the country have been conserved and the public treasury has had ample returns. What might happen if the strict governmental control should lessen is a matter for conjecture only. Although one gains the impression that the present oil development is very large, it is probably true that it doesn't represent a half of the possibilities.

With Professor R. A. Toro, of the University of Puerto Rico, I visited Venezuela during April and May, 1934, making a study of plant diseases and collecting fungous parasites of both cultivated and wild plants. I was especially interested in the plant rusts (Uredinales) and my colleague in the black fungi (Pyrenomycetes). Our activities were in continuation of botanical explorations begun and carried on under the direction of Chancellor C. E. Chardon, of the University of Puerto Rico, himself an enthusiastic collector and an excellent student of fungi. A 350-page volume with 33 plates of illustrations



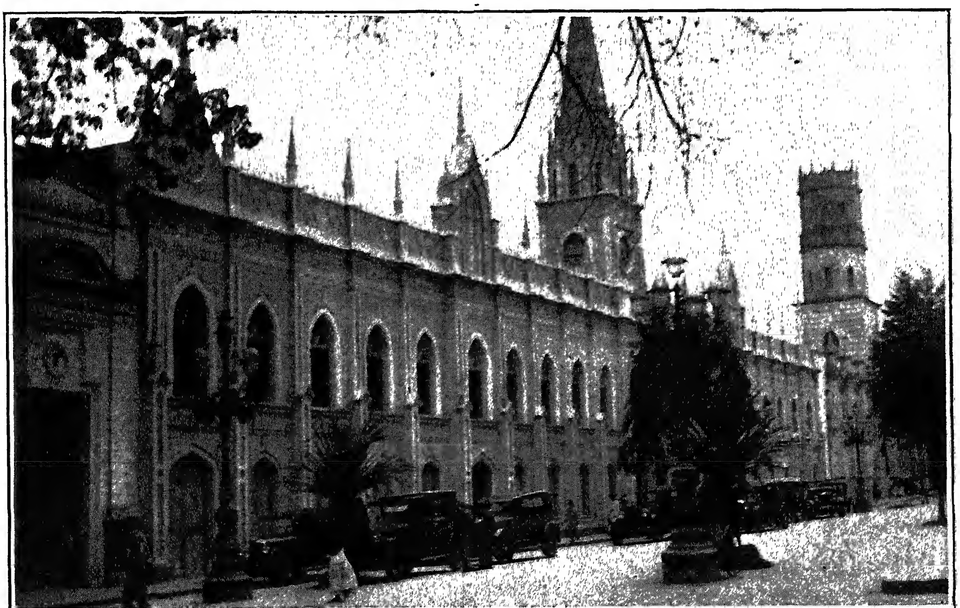
TWIN PEAKS IN THE ANDES OF VENEZUELA
NAMED IN HONOR OF THE EARLY BOTANISTS, HUMBOLDT AND BONPLAND.

entitled "Mycological Explorations of Venezuela" by Chardon and Toro, in collaboration with various specialists, published by the University of Puerto Rico in 1934, is the best evidence of the type of work being done. That volume is founded chiefly on previous explorations made by Chancellor Chardon and Professor Toro in 1932 and reports 667 species of fungi, of which 92 are new to science. Our collections of 1934 have not yet been reported, but preliminary studies indicate that we have several more new species. And of scarcely less interest are the collections which add to our knowledge of existing species. To find a specimen which extends the geographic distribution of a known species or one which adds to our knowledge of its life-history is a real thrill to the collector. On this expedition we collected several species of rust of more than usual scientific interest and several of economic interest. The rust on alfalfa was taken for the first time in northern South America, having been previously reported from Argentina and southern Brazil. We found a rust doing considerable damage to a planting of Guatemala grass. We are reminded of the appearance of this rust in Puerto Rico shortly after Guatemala grass was established as a crop there. It seems likely that the rust will follow the cultivation of this grass. This appears to be the first report of the disease from South America.

Of course, the real pioneer botanical exploration of South America began long ago. The work of Joseph Jussieu, which began in 1747, deserves first mention. He did not touch the region now occupied by Venezuela. Unfortunately he brought back only a few specimens. Humboldt and Bonpland in strenuous explorations at the beginning of the nineteenth century were in the Venezuelan area, and one is reminded of them to-day by two high Andean peaks named in their honor. They explored jungles, forests and mountains and brought back a rich collection which became the foundation of our knowledge of the flora of northwestern South America. Much later we can not overlook the fine work

of Dr. Henri Pittier, who is still living and working near Caracas. We found his book, "Manual de Plantas Usuales de Venezuela," published in 1926, most helpful in determining the hosts of some of our parasitic fungi. We visited Dr. Pittier, and he was kind enough to examine and identify some of our collections. It is impossible to refer here to many of the botanical pioneers in South America. There is a considerable list and they did wonderful work, but the task of working out the tropical flora there was tremendous and it is far from complete to-day. The expanse of tropical area in South America exceeds the United States in extent. I am glad to pay a tribute to the work of the systematic phanerogamic botanists, both to those who did the pioneer work and to those who are carrying on the splendid work to-day in the field and in the great botanical centers of the world. The student of fungi must frequently call on the phanerogamic botanists to classify and name his host plants, and he has, therefore, a real interest in the activities of phanerogamic botanists. I find it necessary frequently to call on these systematists for aid, and I can not be too enthusiastic in expressing my appreciation of their cooperation. They often get imperfect specimens and the cheerful and effective way in which they help in solving these puzzles adds materially to the mycological results.

Mycological studies in Venezuela were initiated by Dr. Adolfo Ernst, who went there in 1861. His devotion to the development of science and education in the country of his adoption earned for him a distinguished standing. The first systematic account of the fungi of Venezuela is the classical work of Patouillard and Gaillard entitled "Champignons du Venezuela et principalement de la region du Haut Orenoque recoltes en 1887 par M. A. Gaillard." Its pioneer nature can be appreciated when it is known that 45 per cent. of the 278 species were new. From the time of Patouillard and Gaillard, the French botanists, Venezuelan

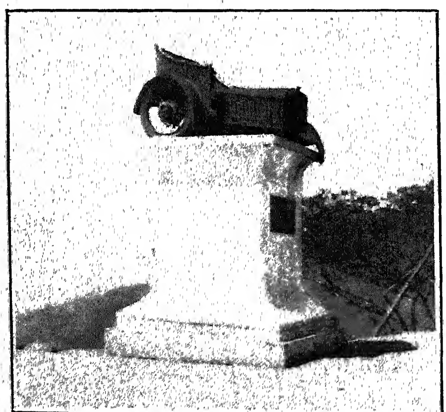


THE UNIVERSITY IN CARACAS

THE BUILDING WAS FIRST USED AS A MONASTERY AND DATES BACK TO THE EIGHTEENTH CENTURY.

STATUE OF LIBERTY
ON ONE OF THE PRINCIPAL STREETS OF CARACAS.

mycology did not show much advance until the visit of the eminent German mycologist, Dr. H. Sydow, in 1927. In his paper "Fungi Venezuelani," published in *Annales Mycologici,* of which he is the editor, Sydow reported 316 species



A ROADSIDE WARNING
TO THE EFFECT THAT RECKLESS DRIVING IS DANGEROUS. ERECTED BY THE ROTARY CLUB OF CARACAS BETWEEN LAGUIRA AND CARACAS.

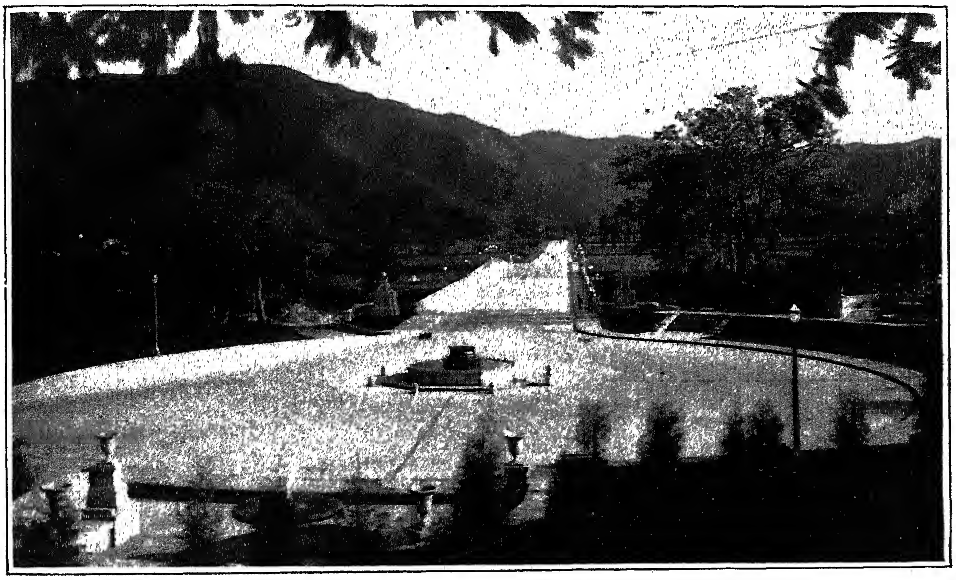
of which 35 per cent. are new. The next mycological work of importance is that of Chardon, Toro and their colleagues, referred to in a foregoing paragraph.

During our recent trip we naturally kept to the field as much as possible, industriously and minutely examining all vegetation in quest of these more or less elusive parasites, yet we found time to make some general observations.

We stayed for several weeks in and about Caracas, which is a most delightful city. It enjoys a perpetual June climate, partly accounted for by its altitude of 3,000 feet. As one sees it to-day there is an interesting mixture of the old and the new. The business sections are old and are characterized by narrow streets and by large numbers of small establishments. Especially noticeable and numerous are the shops of the tailor, druggist and the barber. Larger stores with modern show windows are beginning to come in. The houses in the older sections are all on exactly the same plan. They are built next to the sidewalk with a narrow passage leading to an open *patio,* from which the rooms are entered. The street windows are all provided with window seats and are protected by a projecting iron framework, which extends ten or twelve inches from the wall. This permits an excellent opportunity to remain at home and yet to observe what is going on in the street. The sidewalks are just about wide enough for two people, except for the telephone poles. It is necessary to go single file past the poles. A bird's-eye view of Caracas from the top of one of the surrounding mountains was suggestive at that distance of an enormous tile-yard, since the buildings are uniformly low and the roofs almost exclusively tile. In the newer suburbs the plans are thoroughly up-to-date, with wide streets, beautiful lawns, gorgeous plantings and gardens and houses that are not only modern but often what I would call modernistic. There are several beautiful country clubs, some of

them with excellent golf courses. Another modern feature about Caracas is the number and quality of its automobiles. Possibly the narrowness of the streets by impeding traffic may give an erroneous impression of the number of cars, but certainly there is nothing to discount their fine quality and appearance. Commenting one day to a friend on the fact that all the cars looked so clean and shiny, I was told that there was an ordinance requiring owners to keep their cars washed and polished. I turn out to be favorites if sufficiently emphasized.

There are two North Americans honored with statues in Caracas—George Washington and Henry Clay. An amusing incident is related with regard to the statue of Washington. It has its setting at the time it was necessary to cut down some trees in the Plaza Washington to make way for the building of a theater. It is said that one night a wag went to the plaza and attempted to console the Father of his country on the removal of



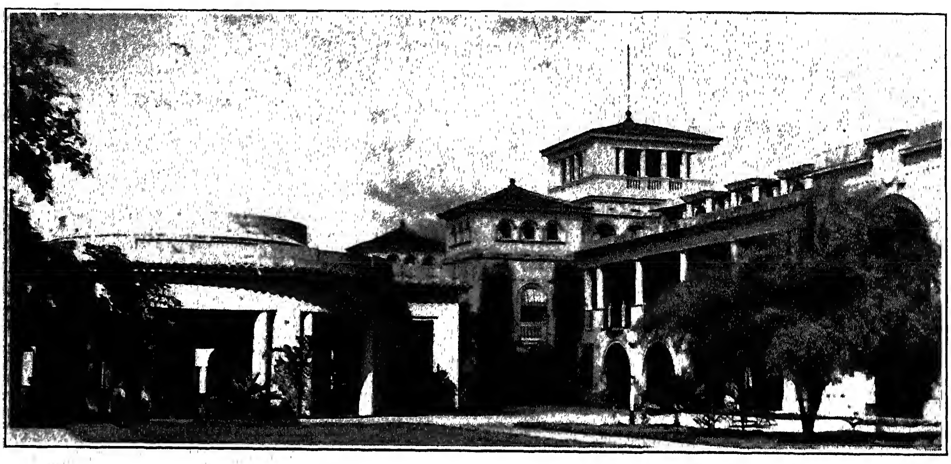
AVENIDA LA PAZ—AVENUE OF PEACE

IN ONE OF THE NEWER SUBURBS OF CARACAS.

suspect I was being joked, but nevertheless the effect was there as if it might be true. Any notes about Caracas would be incomplete without reference to street noises. They are of two main sorts, one the incessant and largely unnecessary honking of automobile horns, and the other the cries of the vendors of lottery tickets. The striking thing in connection with the latter is the persistence in repeatedly announcing the numbers they have for sale, evidently with the belief that their particular numbers may his trees, but receiving no answer from the statue, turned away woefully with the remark, "Anyhow, I suppose you realize it serves you right; for it was you, was it not, who cut down your father's tree?"

Splendid concrete highways radiate in several directions from Caracas. The main traveled one leads to Maracay, a distance of about sixty miles, where General Gomez spends most of his time on his extensive and favorite estate, "Las Delicias." Here in Maracay every pos-

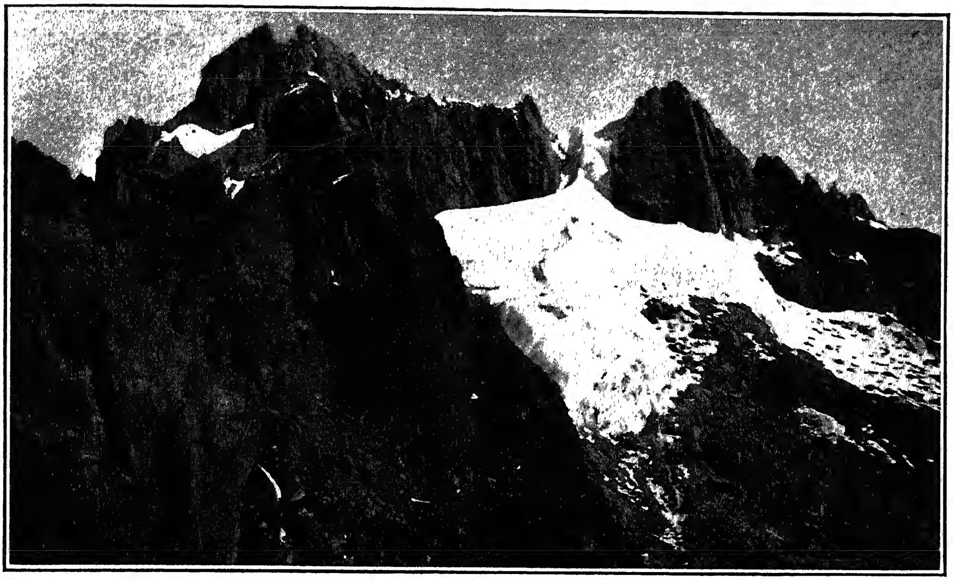
sible travel comfort may be enjoyed in a large and beautiful hotel. As much can not be said for all the towns which we visited. In the fine hotel in Maracay we had the interesting experience of having an employee mix three languages in addressing a short sentence to us. Arriving at our room rather late, we found that clean linen had not been put on our beds. In response to our summons there came a porter who agreed that we were right and who set about to perform the functions of a chambermaid. It is fair to explain in advance that his native language was German, that my friend bantered him in Spanish, and that I chimed in frequently with English. Amid some confusion after he had put on the fresh sheets and finished making the beds he dashed out with the sudden exclamation, "En seguida I bring zwei pillows." On another occasion at a small hotel in an interior town we began to think that we would have to sleep in the hammocks hanging in the room, so slow were they in making up the beds. We were finally provided for in a satisfactory manner, but our chauffeur was not so lucky. The next day we had much fun laughing at his story of how he had to pay an additional fee for each piece of bedding, much to his disgust. One hotel had first-, second- and third-class rooms, reminding one of a steamship. After taking a first-class room we found it a tax on our imaginations as to what second and third class might be like. At another time in a room with two beds I selected a large bed with one of the most gorgeous hand-crocheted spreads I have ever seen, leaving to my companion a plain small bed. At the moment I felt a bit selfish, but I wished to have the experience of sleeping in a bed so grand. My friend had plenty of fun at my expense when it turned out that my grandeur was in appearance only, the mattress resting on boards, whereas his little cot had excellent springs.



"HOTEL JARDIN" IN MARACAY

THE PICTURE SHOWS A PART OF THE *patio*.

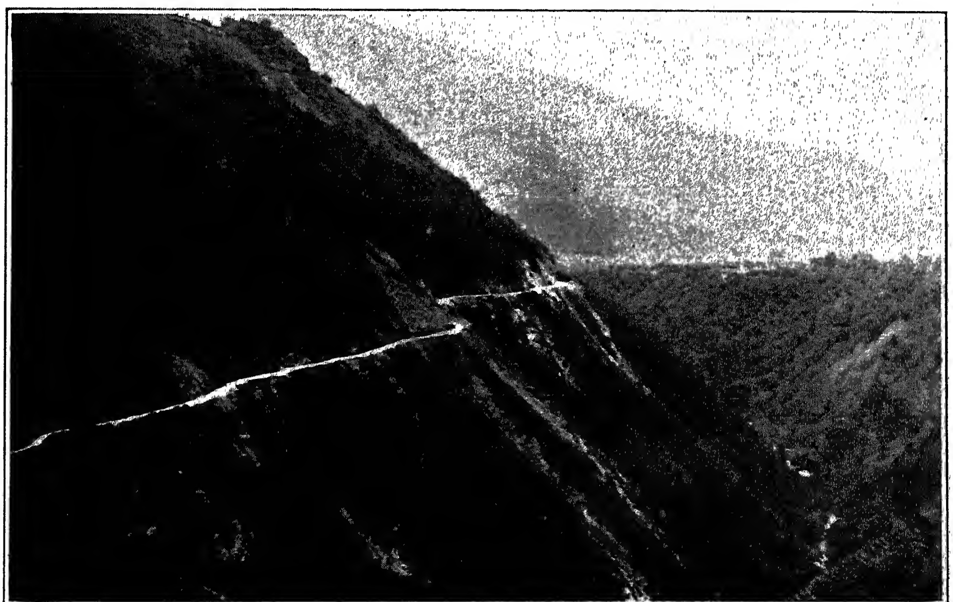
The central and really important feature of our visit to Venezuela was an expedition to the Andes Mountains. We had intended to spend considerable time in the great llanos region, which constitutes about a fourth of the country and lies between the Orinoco and the northern mountains. The llanos are great undulating grass plains, broken here and there by low plateaus and belts of forest. They have been investigated



A GLACIER IN THE HIGHER PART OF THE VENEZUELAN CORDILLERA

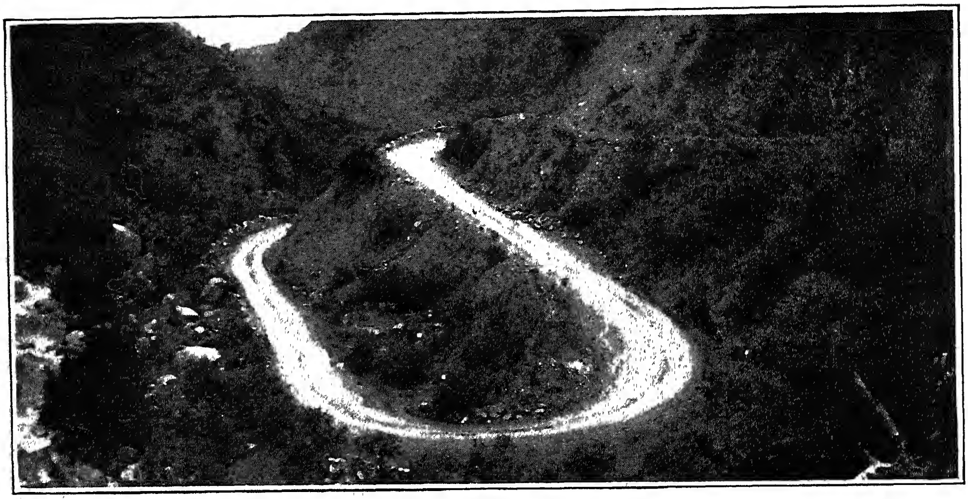
very little botanically. At the time we were there it was toward the end of a long dry season, and we found the plant life so much dried up as to make explorations unprofitable.

Hence after a few days in the western llanos we decided to change our plans and cross over to the great transandine highway, which is a part of the international road between Caracas, Venezuela,



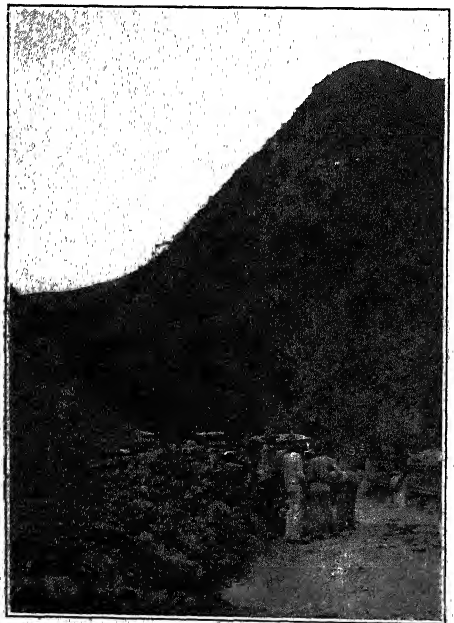
A VIEW ON THE TRANSANDINE HIGHWAY

KNOWN AS THE GRAN CARRETERA DE LOS ANDES, ILLUSTRATING THE NATURE OF A SHELF ROAD CARVED OUT OF THE MOUNTAIN SIDE.



ANOTHER VIEW ON THE GRAN CARRETERA DE LOS ANDES

and Bogota, Colombia. This highway is a magnificent engineering accomplishment and represents a tremendous amount of labor. They tell you there that it is the highest automobile highway in the world. It winds around those great mountains, finally reaching an altitude of 4,080 meters at the highest pass. It seems impossible to present in a word picture any adequate account of the curves and grades. There are many thrills for the traveler. It was nothing uncommon to learn that a village nestled in a valley below was one that had been passed through two or three hours before. The route seemed to have been selected with great engineering expertness and the grading done with accuracy and carefulness. The roadbed needs improving, and the tourist who has been used to guard rails and precautions to prevent rockslides finds much to be desired. Fortunately, traffic is light, and equally fortunate is it that neither course nor surface lend themselves to fast driving. A passenger in an automobile accustomed to speedometer recordings in miles is pleasantly misled by the recordings in kilometers. I am sure that a reading of 30 on the speedometer has a psychological effect different than its equivalent of 18 would have. Many hours through the mountains our speedometer was registering not over 30 kilometers or about 18 miles per hour.



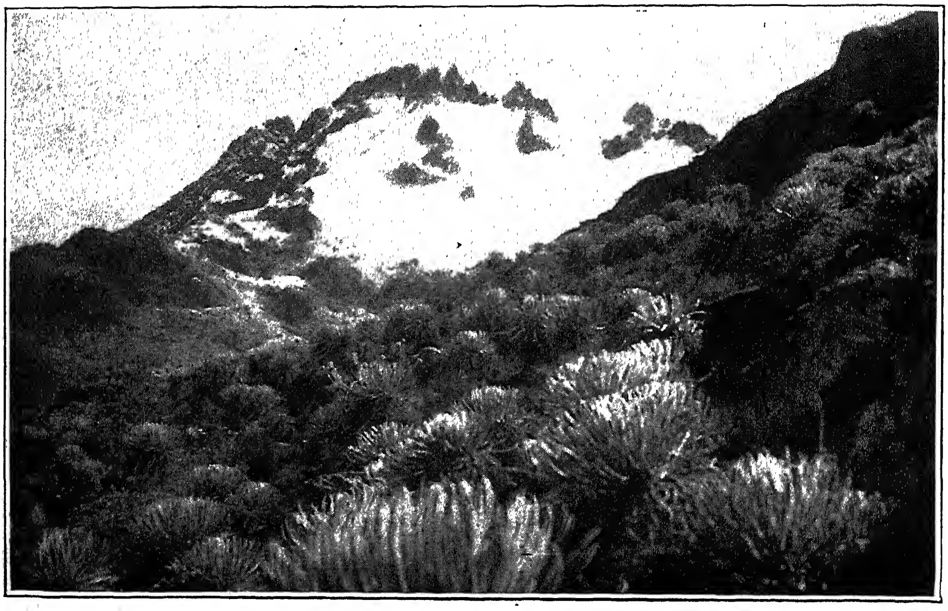
A LANDSLIDE ON THE HIGHWAY

CARS ARE WAITING WHILE WORKMEN CLEAR AWAY THE ROCKS.

After we reached the transandine

DON FELIX RAMIREZ CARILLO, WITH HIS WIFE
IN FRONT OF HIS HOUSE IN CHACHOPO. HE GUIDED THE PARTY OF CHANCELLOR CHARDON TO THE WILD POTATO COUNTRY. THE COBBLESTONE STREET IS TYPICAL OF MANY VILLAGES.

A WHEAT FIELD IN THE ANDES OF MERIDA
ALTITUDE 2,600 METERS. PARAMO COUNTRY ABOVE, IN THE SKY LINE.

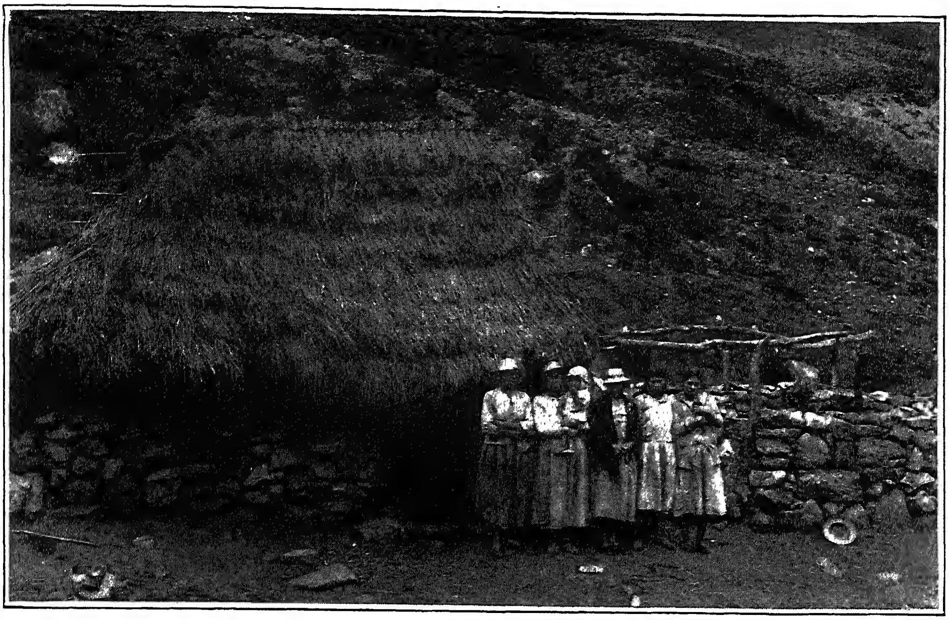


VEGETATION IN A TYPICAL PARAMO REGION

THE CONSPICUOUS WOOLLY PLANT IS A COMPOSITE KNOWN TO BOTANISTS AS *Espeletia corymbosa.*

highway we found that we had some real desert to traverse before we began to ascend the high mountains. Our road must have taken us at least a hundred miles through this region, which is known as the Desert of Lara. The xerophytic flora is characterized by columnar cacti and low spiny trees of the mimosa family. A mistletoe was found growing on some of the trees, and on it we collected an interesting rust. For a considerable distance in the desert the road followed the dry bed of what is a stream during the rainy season. Fortunately the rainy season is short, for it very successfully interrupts traffic. It was just before crossing this desolate region that we were warned about "economic fever." An interest on our part in a malady with such a strange designation elicited the explanation that the name was appropriate because the disease was so quickly fatal that it precluded the possibility of calling a doctor.

Without doubt the most interesting experience in roaming up and down these towering mountains is that of passing from zone to zone as if one were darting back and forth between the tropics and the arctics. Both one's feelings and the vegetation reveal the similarity in effects produced by altitude and latitude. The kaleidoscopic view from the tropics to snow here in the shadow of the equator is impressive. Starting with the heat and flora of the tropical jungle, it seems more or less an imperceptible change to the subtropical zone with its citrus, coffee, bananas and sugar cane. The temperate zone is more clearly defined and the presence of wheat, barley and potato fields, apple and peach trees attract the immediate attention of the northerner. The wild flora in the temperate zone is characterized by plants with thick leaves. It seems as if composites predominate. Ferns are abundant. At the high altitude of about 3,000 meters there begins what is known to the Spanish-speaking people of this region as the "paramo" country. Here the most characteristic plant is a large



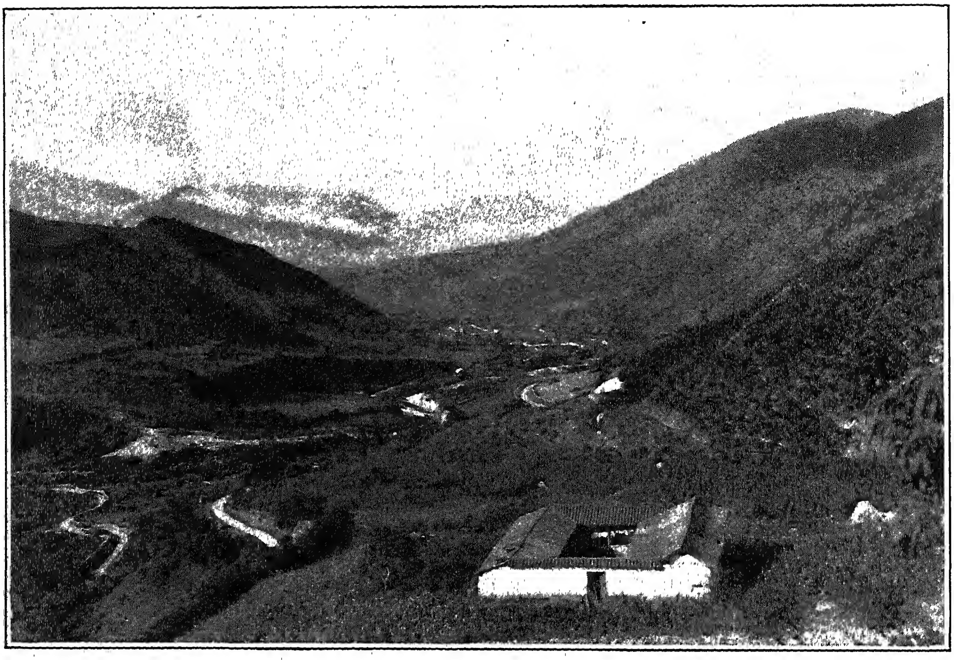
A GROUP OF INDIANS IN FRONT OF THEIR HUT
WHICH IS BUILT OF STONE AND STRAW. PARAMO DE TIMOTES, ALTITUDE 3,700 METERS.

somewhat bushy composite, the leaves and flowers of which are covered with a dense woolly coating. It belongs to the genus *Espeletia*. I am sorry I have no common name for it. In Venezuela it is known as *frailejon*. Gentians, Verbenas, Lupines, Thoroughworts and Cudweeds are in evidence, but the flora becomes thinner as the altitude increases. Above 4,000 meters there are no trees. A common shrub looking somewhat coniferous is a St. Johnswort. The leaves of this give off a disagreeable odor, especially while drying. The *Espeletia* is quite at home above the tree line.

These higher altitudes known as the "paramos" are very sparsely inhabited. Most of the people we saw were Indians, who seemed to be eking out a miserable existence in poor houses with stone walls and thatched roofs. Neither crops nor animals thrive, and why these people stay there at all seems a mystery. In the temperate and subtropical zones the houses are adobe with tile or metal roofs. The climate is mild, farming is successful, and life is pleasant.

Dr. Chardon, in a bulletin of the Pan-American Union published in 1933, has discussed the life zones of the Andes of Venezuela at some length. He recognizes four altitudinal life zones, tropical, subtropical, temperate and paramos, which, he says, correspond to *teirra caliente, tierra templada, tierra fria* and *paramo* of other authors. These last four are the names generally in use in Venezuela, Colombia and Ecuador. Dr. Chardon calls attention to the fact that on the transandean road between Motatan, with an altitude of 340 meters and luxuriant tropical life, and the Paramo de Mucuchies, with an altitude of more than 4,000 meters and a temperature close to freezing, all the four life zones can be passed through within a five-hour journey.

I quote the following from Chardon's account. "As far back as Humboldt and Bonpland's trip to the New World



ONE OF THE TEMPERATE ZONE VALLEYS

AT THE ENTRANCE TO THE GREAT CORDILLERA. THE PICTURESQUE VILLAGE OF TIMOTES IN THE DISTANCE. THE ELEVATION HERE IS ABOUT 2,000 METERS. AN ADOBE HOUSE WITH TILE ROOF IN THE FOREGROUND.

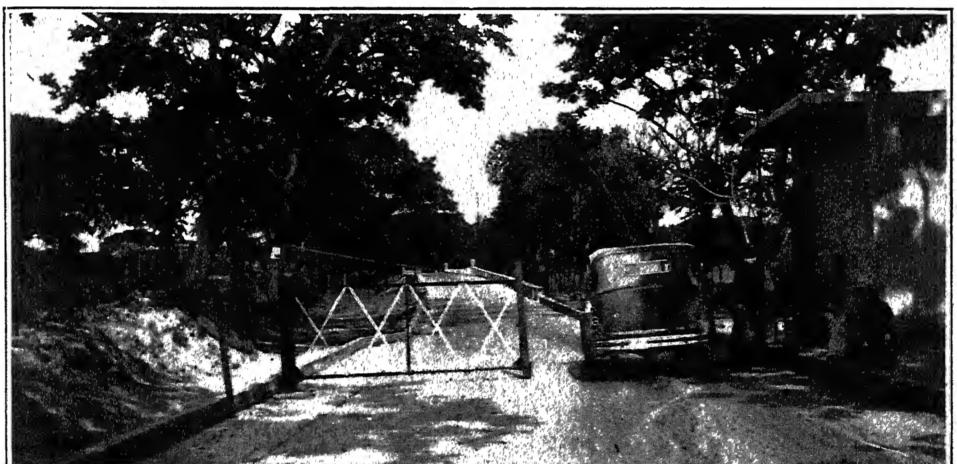
(1799–1804) the Andean Cordillera was known to be divided into distinct life zones. These scientists made accurate observations on the altitudinal distribution of plant life, especially in the description of the paramos. The Colombian Francisco Jose de Caldas added to our knowledge of altitudinal distribution and its effect on Andean agriculture. Dr. Alfredo Jahn, of Caracas, in his geographical studies of the Andes of Merida ("La cordillera venezolana de los Andes," 1912) and in a recent paper read before the Sociedad Venezolana de Ciencias Naturales ("Los paramos venezolanos," 1931) has made extensive observations and discusses specifically the paramos of the Venezuelan Andes. In Dr. Henri Pittier's flora (previously mentioned) appears a detailed treatment on altitudinal zones. Dr. Frank Chapman, in his bird studies of Colombia (Bulletin of the American Museum of Natural History, 1917), gives an excellent discussion of life zones of the Andes and their altitudinal distribution. His work is cited here as one of the most interesting contributions to Andean natural history."

Any story of travel in Venezuela which does not touch on the gates, chiefly at entrances to the cities but sometimes at state lines, would be woefully incomplete. The government wishes to know who is traveling and where and the records taken at these gates furnish this information. An automobile trip has frequent interruptions, while these gatekeepers check up on you. They record the names of all the passengers, the chauffeur, name and number of the car, and they do not forget to ask where you are from and where you are going. At most of the gates policemen in uniform

are in charge and in evidence, but sometimes only a boy is encountered. There seems to be a variation in the care and enforcement of the regulations. At some gates, especially at state boundaries, there is a tendency to search luggage. I state it in this way because if there is a rule to that effect it is often disregarded. At one place an officer told us that they really inspect the face more than the baggage and on that basis he knew we were honest and would make no inspection. It seemed more likely to us that something in the nature of our credentials influenced his decision to let us off so easy. At another gate we were required to wait a considerable time while a careful and complete record of our credentials was made. When we returned through this same place some days later, there was no formality and we were much amused by the instructions of the officer in charge to the gate keeper, "Let them pass, I know them very well."

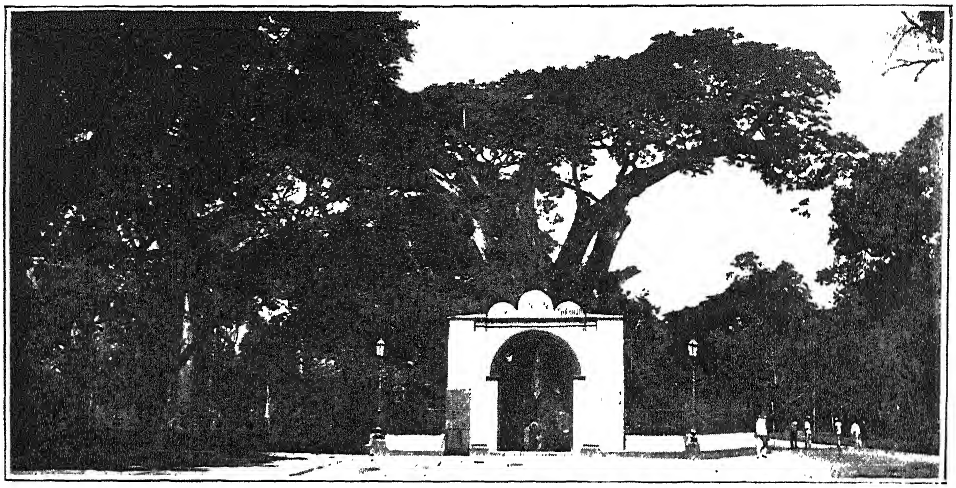
Not long ago I saw a despatch in one of our papers to the effect that an automobile trip through Venezuela is anything but a joyride under present conditions and mention was made of the frequent stops and the ransacking of baggage by suspicious officials. It was our experience that a good deal depends on the attitude of the traveler. It was necessary to comply with regulations, but at no time was there anything unpleasant about what was required and everywhere the finest respect was paid to us and to our credentials. Sometimes we were told to go to the office of the *jefe civil* (might correspond to mayor) to register before going to a hotel. We always did it and we found all officials with whom we came in contact to be friendly and helpful. It is my idea that those who get into trouble in such places are the ones who think that they have the right to decide whether or not they will comply with regulations.

In an article on the progress of botanical exploration in South America (*Bulletin* of the Torrey Botanical Club, 1932) Dr. H. A. Gleason has called attention to the tendency that botanical explorers have shown to give way to their enthusiasm by collecting first in the region of their port of arrival and then when starting inland to follow established



ONE OF THE "REGISTRATION" GATES

THE SPANISH DESIGNATION IS *alcabala*. SOMETIMES INSTEAD OF ACTUAL GATES THERE ARE HEAVY CHAINS STRETCHED ACROSS THE ROAD FASTENED TO POSTS ON EITHER SIDE.



AN ANCIENT SAMAN TREE

THIS IS THE CHIEF SPECIES OF TREE USED FOR COFFEE SHADING.

roads or trade-routes for long distances. He points out that in this way the collecting of an explorer tends to overlap that of his predecessors. As I look back on our visit to Venezuela and particularly as I have here given an account of it, I believe my companion and I must plead guilty to having done what others have done. But Dr. Gleason has offered such a splendid defence of this natural tendency that I am tempted to quote. "This is not said in criticism," he writes. "Quite on the contrary, it is this repetition of work in the same territory that has been necessary to discover and collect the flora. Even yet that work is not absolutely complete, not even for small districts about the seaports, or for the frequented trade-routes. I venture to say that there is not in all tropical South America a tract of a hundred square miles with its flowering plants all known and listed. Finding the first half of a flora is easy. Finding the next forty per cent. is interesting, having the excitement of discovery without the necessity of too great exertion. Finding the last ten per cent. means long continued work, and an effort probably quite out of proportion to the interest or value of the results." Mycologically we have found so far only those things which are in the first half and so I think no apology is necessary for having taken routes that overlapped those of previous collectors.

For the success of our expedition thanks are due and are hereby accorded to numerous officials and friends. We are especially indebted to the President, and to the Ministers of Agriculture and Education, and members of their staffs for material aid. Several of the photographs included in this paper were made available through the kindness of Dr. Chardon. We were fortunate in coming in contact with a considerable number of people who encouraged us and gave us assistance of one sort or another. In this group is included the American ambassador. We wish it were possible to mention all these good people by name. We long for an opportunity to repeat these pleasant experiences.

THE PROMISE OF MODERN BOTANY FOR MAN'S WELFARE THROUGH PLANT PROTECTION

By Dr. E. C. STAKMAN

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BOTANY is the most important of all sciences, and plant pathology is one of its most essential branches. The statement is hyperbolic, of course, but it is not mere bombast. For man still is basically dependent on plants for subsistence. Plants are the sole creators of food and clothing materials; man and other animals are merely cultivators, transformers, processors or purveyors. When we consider the manifold additional uses of plants and plant products, including their service in building and conserving soil, in controlling floods and in increasing the esthetic enjoyment of life, the assertion in the first sentence could at least be defended in argument. At any rate it is well to remind ourselves occasionally that human subsistence is dependent on plants and that the number of people that can exist in the world is limited by its agricultural and aquicultural potentialities.

If plants are essential, it follows that their protection also is of paramount importance. Plants need protection against unfavorable soil and weather, against certain industrial by-products, against insect pests, against diseases caused by bacteria, fungi, eel-worms and other living organisms, and against filterable viruses. Crop plants may be severely damaged or commercially ruined by any of the above causes. It would be desirable but hardly feasible, within reasonable limits, to discuss the devastation caused by all these factors. Therefore, this discussion is restricted principally to plant diseases caused by plant parasites, except in so far as other factors must be taken into consideration in controlling them.

Ever since the dawn of recorded history plant diseases and insect pests have been among the greatest hazards in the production of crop plants, and they still are. It has been estimated that insect pests cost the people of the United States approximately a billion dollars annually, and plant diseases are about as costly. Plant pathologists and entomologists often are ridiculed for their allegedly extravagant estimates of damage caused by diseases and pests. But any one who has seen the devastation caused by epidemics of black stem rust of wheat and other small grains, by late blight of potatoes, by grasshoppers and by many other diseases and insects must be profoundly impressed with the magnitude of the financial losses, the tragic consequences to farmers and the far-reaching sociologic and even political implications of such crop catastrophes.

While the control of insect pests is not primarily a botanical problem, the relation of insects to many plant diseases is so important that a discussion of plant protection would not be complete without at least brief reference to it. Insects are the principal or only agents of dissemination and inoculation of many plant pathogens. In popular language, insects are tremendously important in spreading plant diseases. They are responsible for the spread of some of the

most destructive virus diseases, such as curly top of sugar-beets, aster yellows, sugar-cane mosaic, raspberry mosaic and many others. They also are largely or wholly responsible for the dissemination and inoculation of the bacteria or fungi that cause rots of potatoes and other vegetables, pear blight, the Dutch elm disease, wilt of cucumbers and related plants, and certain wood stains and rots of felled timber. So important are insects in connection with many plant diseases that disease control becomes a joint entomological and botanical problem. And the protection of crop plants against many insect pests themselves may well be accomplished by botanists through the breeding of resistant varieties. This method of controlling insects has not been used extensively, but there is evidence that it may become very important. Modern botany can promise much for the control of certain insects, but close cooperation between entomologists and botanists can promise still more.

How important is it to protect plants against diseases? Far more important than often is supposed. In a Mayo Foundation lecture several years ago Professor Whetzel pointed out that one third of the sweet potato crop of the United States is destroyed annually by diseases in the field or in the storage house, "one bean in every dozen, one apple in every seven, one peach in every eight, one bushel of Irish potatoes in every twelve, and one bushel of wheat in every ten, are destroyed annually by diseases in these crops." It is stated further that certain potato growers in Pennsylvania have increased acre yields of potatoes between 300 and 500 bushels over the average of the state by using disease-free seed and by spraying. In Minnesota, a number of years ago, yields of potatoes were increased 160 bushels an acre in demonstration plots through the use of disease-free seed. Yields of wheat have been almost doubled in experimental plots dusted with sulfur to control rust. The terrific stem rust epidemic of 1935 destroyed 12 per cent. of the wheat in Kansas, 15 per cent. of that in Nebraska, about 30 per cent. of that in South Dakota and about 60 per cent. of that in Minnesota and North Dakota. The total toll taken by rust in that one year was more than 125,000,000 bushels. The terrible devastation over thousands of square miles can scarcely be realized by any one who has not seen it himself. And epidemics of other diseases can be equally destructive over considerable areas. Thousands of acres of sugar beets are periodically abandoned because of the ravages of the curly-top disease; the chestnut blight has practically destroyed the chestnuts of the United States; and the Dutch elm disease is now menacing one of our finest shade trees. And these are only a few examples. Surely the protection of plants against diseases is of national concern.

Fundamental to crop protection is better crop adaptation. Just as nature has selected ecotypes of native plants, that is, strains particularly suited to certain soil and climatic conditions, just so must the crop ecologists or breeders select strains of crop plants that are particularly suited to certain environmental conditions. For drought, excessive summer heat and winter cold are grave hazards for crop plants. Their destructive effects are both direct and indirect. Several million acres of winter wheat are abandoned each year because of winter injury; about 15,000,000 acres, or one third of the total planted, having been abandoned in 1933; fruit trees are periodically killed or severely injured by cold, and during the drought years of 1933 and 1934 about a billion bushels of corn were destroyed by heat and drought. The weather can not be controlled, but its destructive effects can be reduced by developing adapted varieties and by the use of suitable cultural practices. Much has already been

accomplished. The substitution of Crimean wheats for Mediterranean types in the Southern Great Plains area has greatly reduced losses from unfavorable weather; the development of Minturki wheat has made winter-wheat growing safer on the northern fringe of the winter wheat region; the development of Ceres wheat has reduced somewhat heat and drought injury in the northern spring wheat region; the development of early maturing varieties of wheat and corn has reduced danger of damage by early frosts; and the development of stiff-straw varieties of small grains has reduced the danger of lodging on soils where it was common. But far more can and should be done. When we consider the terrific losses of recent years, the need for varieties still better adapted to resist unfavorable weather and soil conditions is apparent. And past progress indicates the possibility of greater accomplishment for the future. But superior varieties are not plucked out of a hat by tricks of legerdemain; they are the result of long and painstaking and laborious sorting and breeding and testing. The breeding of better adapted varieties is not a pastime for botanists in their spare moments. It requires time, labor, skill and adequate facilities.

Crop adaptation also is an aid in controlling some plant diseases caused by pathogens, particularly those that attack weakened plants. For unsuitable environment often predisposes plants to insidious but destructive diseases. Certain root rots of cereals, for example, are most destructive to plants weakened by unfavorable environment. Canker fungi and wood rots are likely to attack fruit trees that have suffered winter injury. There even is evidence that resistance to stem rust may be lowered when normally resistant wheat varieties are grown under environmental conditions to which they are unsuited. It is becoming increasingly evident that plant disease resistance is a variable character that is governed not only by genetic factors but also by environment; hence, the importance of having varieties well adapted to local soil and climatic conditions. While this is especially true of long-time perennial crops, it is true also of annual crops. Some European countries have long recognized the necessity of breeding locally adapted varieties, and there appears to be increasing appreciation of its importance in the United States. The desire for standardization, however, sometimes has resulted in growing varieties under conditions to which they are not suited. The breeder of locally adapted varieties can contribute significantly to plant protection.

A primary obligation of botanical science is to help promote what may be termed plant public health. And one way of accomplishing it is by preventing the promiscuous interchange of dangerous plant pathogens between regions and countries. This requires more knowledge, better techniques and better social attitudes. There are those, of course, who are opposed to plant quarantines on the ground that they are unnecessary or ineffective. But surely one can scarcely contemplate with serenity the devastation caused by chestnut blight, the total cost of citrus canker in Florida and other Gulf States, the economic importance of white pine blister rust, and the menace of the Dutch elm disease to our finest shade tree. These diseases are caused by pathogens that were brought into the country by man and could have been excluded by quarantines. And they are only a few of the total, to say nothing of introduced insect pests. When one reviews the history of many of the most destructive diseases, it is astounding to find how many of them have attained their present status through the activity of man himself. Many of them originally were restricted in importance and

geographic distribution; they could not have crossed natural barriers such as high mountain ranges, oceans, and even crop barriers, by natural means. But man, because of ignorance, apathy, carelessness or lack of foresight, did what nature could not do. He carried them to the far corners of the earth, where they often have persisted in their most pernicious form.

There is great potential danger in transporting propagative parts of plants from one part of the world to another, because a disease may be far more destructive in a new region than in one where it has long existed. The varieties grown in the new region may be far more susceptible than in the region where the disease has long been prevalent, or the weather and soil conditions may be more favorable. Because a disease is relatively unimportant in one region is no guarantee that it will be unimportant in all regions. The chestnut blight is far more destructive in North America than in its original home in the Orient because the American chestnut is very much more susceptible to it than oriental species. Citrus canker was not recognized as a destructive disease until it found extremely favorable conditions in its new home in Florida. Plant breeders repeatedly have developed disease-resistant varieties of crop plants, only to see them succumb to new parasitic races of the same pathogen which may have been introduced from other regions. The danger of introducing new strains of a pathogen is well illustrated by the fact that Anthony oats is fairly resistant to stem rust in the United States but completely susceptible in certain areas of Northern Europe, merely because different races of the stem rust fungus prevail there. There are similar situations with respect to other rusts, smuts and other destructive pathogens. Surely there is ample evidence that quarantines are desirable if they can be made effective.

Can quarantines be effective? The question can not be answered categorically. Obviously, the success of any quarantine will depend on the method of dissemination of the pathogen involved, on the nature of the barriers between the area where the disease occurs and the area to be protected and on the adequacy of the quarantine organization. Obviously there should be a scientific basis for every quarantine. This often has been lacking, and things have been done that need not have been done, and things have not been done that should have been done. The quarantine on Maine potatoes, about twenty years ago, because of powdery scab was costly, but it was neither effective nor necessary, because the disease already was present in one region that the quarantine was designed to protect and could not develop destructively in another because of unsuitable environment. It was a mistake. But whose fault was it? Not the quarantine organization's! Their action seemed justified on the basis of the available information, but there was not enough information available. The fault was with those who failed to provide for adequate plant disease surveys. And one reason clearly was the difficulty of overcoming the inertia or resistance of many people who refused to consider seriously what might happen but only what had happened. There is serious danger in having thoughts rooted too deeply in the immediate present or in the past.

Practical botanical science must project itself more into the future; and to do so it must not be too practical. For science surely has the obligation to forecast the future, not only to explain the past and present. Observations and researches should be made to find out where potential as well as present danger lurks. This can be done only by studying diseases over as wide a territory as is necessary, whether domestic or foreign. Domestic plant disease surveys are essential from a number of standpoints. Un-

fortunately, however, their value often is not recognized. It is pertinent to ask how plant pathologists can be expected to meet new situations, to interpret old ones and to prepare for future emergencies if they do not have opportunity to make adequate studies of diseases as they exist and the factors influencing their distribution and development. Plant disease survey studies, ecologic studies, are among the most important in the whole realm of plant protection, and yet we are often so myopic as not to appreciate their value and provide for their support.

In addition to domestic plant disease surveys, every country should interest itself in the diseases of other countries, especially those that grow the same kinds of crops. Information should be obtained regarding the methods of effective dissemination and the effects of the parasitic races of the foreign pathogen on the crop varieties and under environmental conditions similar to those of the country to be protected. Only when such information is available can the most adequate and intelligent quarantine action be taken. When we consider our own experience with chestnut blight, citrus canker, white pine blister rust and the Dutch elm disease, and the experience of many foreign countries with other diseases, we can scarcely avoid the conclusion that quarantines are essential; and, when we consider certain other cases, we must admit that unfortunate mistakes have been made in their application. The remedy, however, is not wholesale condemnation, but improvement through the results of research. And the research must precede practice, not lag behind it and do the second guessing.

The principles that apply to quarantines apply equally to eradication campaigns. Unfortunately, even some botanists still maintain a scornful or sceptical attitude toward large-scale eradication as a control measure. This was true also of many medical men when medical science entered the field of public health. If it is considered demeaning for botanists to assume leadership in plant public health measures, at least no one needs demean himself unless he chooses. Every scientist has a right to his scepticism, but he also has the obligation to study each situation honestly and thoroughly before pronouncing destructive *dicta ex cathedra.*

Some eradication campaigns have succeeded; others have failed. Some have been modified with respect to aim and scope; others were carried out as originally conceived. The difficulty is that emergency or public demand precipitated some of them before scientists were ready to supply the best techniques or accurately to predict the probable outcome. The chestnut blight eradication campaign failed; the citrus canker eradication campaign in Florida was conspicuously successful. The white pine blister rust campaign was not successful in completely eradicating the disease from the United States, but it has been eminently successful in controlling the disease for practical purposes in New England and the Lake States. The barberry eradication campaign has been successful in eliminating a tremendous number of annual local and regional epidemics of stem rust throughout the eradication area and in causing a downward trend in average annual rust losses. It has not resulted in complete elimination of general epidemics, but has reduced their frequency and is a practical control measure in the more eastern states of the area. Furthermore, the indirect benefits are almost incalculable. The existence of parasitic races of stem rust is one of the greatest handicaps to the development and maintenance of rust-resistant varieties. Varieties have been distributed as rust resistant, have retained their resistance for some time, and then have become susceptible because of the appearance of new or hitherto

unimportant parasitic races. Researches on the genetics of the stem rust fungus show that these new races are produced principally, if not almost exclusively, by hybridization on the common barberry. Almost 150 of these parasitic races are known, and there is definite evidence that new ones are produced and perpetuated through the agency of the barberry. From the standpoint alone of preventing the future development of new races and reducing the number now in existence, the barberry eradication campaign is worth-while. The most recent experience with parasitic races was in the crop season of 1935, when Ceres wheat, hitherto moderately to highly resistant to stem rust, succumbed to its ravages because of a combination of factors, including the prevalence of a relatively new physiologic race to which it is very susceptible under certain conditions. Is it too much to expect that some of the wider implications of such control measures as barberry eradication should be understood and appreciated?

Both white pine blister rust eradication and barberry eradication often are criticized because of changes in objective, method or, in some cases, unguarded statements regarding probable results. Unfortunately, it is impossible here to discuss fully the merits of the questions involved. However, both campaigns have paid for themselves many fold. Before condemning them because they do not eliminate the diseases completely, it would be well to picture what would have happened had they not been undertaken. Surely it should not be difficult to appreciate the value of a disease control measure that contributes significantly to the alleviation of a situation, even if it is not perfect or if it must be used in conjunction with other methods. The fact that techniques were modified or simplified and that the work could often have been done more economically and effectively had all necessary facts been available at the beginning merely strengthens the argument that research should not only accompany but also precede control measures. A highly significant contribution of modern botany to man's welfare will be to provide a technical service to accompany every control program and, particularly, to accumulate through research a reservoir of facts to be available as soon as necessity arises, not years afterward.

Botanical science can and should function far more effectively in future than in the past in protecting long-time pasture and forage crops against short and unprofitable life because of the inroads of insidious diseases. The increasing emphasis on grassland and forest creates new problems. Obviously, direct control of diseases often is difficult or impossible with such plants, and mistakes can not be rectified so easily as with annual crops. If a mistake is made with annual crops, it can be avoided the next year. But when pastures are established or forests planted, they constitute a long-time investment and changes to rectify mistakes are expensive. Therefore there must be adequate research in order that the mistakes may be prevented, that the most suitable kinds of plants be provided and proper cultural practices devised. Considerable is known about diseases of individual grasses and forage crops, but too little is known about the relative value of different strains, the relation of pure and mixed stands to the development of diseases, about the relation of soil type, site and fertilization to yields and longevity. And in many cases still less is known about the relative disease resistance of strains or biotypes within a species. At the Welsh Plant Breeding Station, Aberystwyth, the writer saw, a number of years ago, a large number of strains of orchard grass, *Dactylis glomerata*, which had been selected in the vicinity and propagated vegetatively. Not only did they differ greatly in growth

habit and other important characters, but some of them were virtually immune from yellow stripe rust, while others were completely susceptible. Obviously, such selection work and the incorporation of the results into agronomic practice is extremely valuable. The ecology and pathology of grasslands must be studied thoroughly if costly mistakes are to be avoided. They can and should be avoided, but botanical science must be put to work on the problems if they are.

Better protection of forest trees against diseases and deterioration due to wood rots is imperative if the land devoted to forests is to be used to best advantage. Necessarily, improvement must be attained through incorporation into silvicultural practice and forest management of the results of research. It is known, for example, that Armillaria root rot causes heavy damage to many of the most valuable tree species. But what is the relation of pure or mixed stands, density of stand, site and other factors to its development? This information should be utilized when the plantings are made. Likewise, the relation of similar factors to the development of canker diseases and wood rots must be learned and appropriate measures taken. In northern Europe it has been shown that larch canker is likely to be much more destructive in pure stands than in mixed ones, and this fact is taken advantage of in practice. With the increasing emphasis on managed forests in the United States, similar facts should be taken into consideration. Thinning operations, cutting methods and cutting cycles must be arranged with due regard to the protection and performance of permanent forests and woodlands. The art of growing healthy trees must be based more and more on scientific principles, but the scientist who discovers them and recommends their application also must learn more about the art of growing trees—not only in pots in the greenhouse, but in the woods. And he must learn more about the pathogens of the trees—not only on nutrient agar, but on the trees themselves. What is known, for example, about the relative resistance of biotypes within tree species? Almost nothing. But yet there are such biotypes, differing profoundly in growth characters and in disease resistance. On a private estate in Germany, for example, the writer recently saw plantings made from different seed lots of Scotch pine. The plants were growing under comparable conditions, but yet plants from different seed lots differed strikingly in rate of growth, growth habit and resistance to the leaf-cast disease. The trees in some of the plots were almost completely defoliated by the leaf-cast disease, while those in others were virtually immune. It was a beautiful demonstration of the existence of races or strains within a tree species. The importance of the application of genetic principles, particularly with respect to the selection of planting stocks, can hardly be overestimated. And even scientific breeding of trees is not a mere dream; a beginning has been made, and the possible value has been shown. The forests of the future can and will be far better than those of the present if science is given greater opportunity to function in their establishment and maintenance.

In the future far more will be done than in the past toward protecting crop plants against soil-borne diseases through cultural practices, including soil fertilization, time of sowing and rotation. The discovery that corn is predisposed to root and stalk rots by lack of sufficient phosphorus and potash; the discovery that early sowing of flax is likely to prevent serious injury by Fusarium wilt; the discovery that damage from fusarial head blight of wheat and barley can be greatly reduced by not sowing them on corn land suggest the possibilities of accomplishment in this direction. But there still is a vast field for exploration

and a rich reward in results of practical value in this phase of crop protection. How little is known, for example, about control of diseases caused by so polyphagous a species as *Rhizoctonia solani?* And yet there are definite indications that study of physiologic specialization in this species will yield results that can be applied with great profit in growing such important crops as sugar-beets, potatoes, tomatoes and other vegetables.

Investigations of antibiosis hold great potential promise for the future. It is known that some microorganisms have a tendency to inhibit or prevent the growth of others, including plant pathogens. Certain bacteria are known, for example, that prevent the development of smut fungi. Certain fungi are known that prevent the development of Rhizoctonia and other generalized parasites. It is one of the commonest observations in cultural work that fungi growing together may have no effect on each other, may stimulate each other, may be mutually antagonistic, or one may prevent the development of the other. This phenomenon has been studied in the past principally because of its scientific interest, but in future it should be studied also because of its potential practical importance. A beginning has been made, and promising results have been obtained. From these results it seems certain that the information obtained can be applied, at least on a small scale, to the protection of valuable ornamentals, and possibly of fruit trees. There even is promise that it can be used on a large scale in helping to devise cropping systems that will enable antibiotic organisms to function significantly in controlling such destructive and refractory diseases as potato scab, root rots of cereals and probably many others.

Chemical immunization of plants has been attempted so often and with such indifferent results that many plant scientists have concluded that it is impracticable. But recent results obtained by Hassebrouk in Germany show that it is definitely possible and possibly practicable.

Past progress in the control of diseases by fungicides, in cooperation with chemists, points the way to extensive progress in the future. The step from copper sulfate and formaldehyde to the best organic mercury dusts was scarcely dreamed of twenty-five years ago. And yet these most recent fungicides have largely eliminated the danger of seed injury, are much easier to apply, and they control certain diseases that resisted control entirely by the old fungicides. Then, too, there will be tremendous progress with respect to the specific applications of fungicides. The investigations at Cornell University showing that in some localities potato yields are increased greatly by increasing the proportion of copper sulfate to lime in the bordeaux spray, while the reverse is true in other localities, show how little we know and how much can be accomplished by precise investigations of fungicides and their effects. There is tremendous need for information regarding effects of different fungicides on different crop plants, on different pathogens and under different conditions. It is to be hoped that the "squirt gun days" of plant protection are on the way out; but they will linger on until there is wider appreciation of the necessity for investigations made on an adequate scale and with the required degree of precision.

There is great promise in the control of plant diseases through the development and use of resistant varieties. Indeed, some diseases can not be controlled economically by any other means. Flax wilt, wilt of peas, tomato wilt, asparagus rust, cabbage yellows and some rusts of cereals are now being more or less completely controlled by growing resistant varieties. But a vast amount of laborious work and research is required to insure

sound and substantial progress in breeding resistant varieties. It is not always easy to combine disease resistance with other required characters. Neither is it always easy to combine in one variety resistance to all the important diseases in the region. And even if a new variety is resistant, it may prove very susceptible to hitherto unimportant diseases. Nor does a variety necessarily remain resistant permanently.

The difficulty of combining all desirable characters in one variety and of foreseeing what is likely to happen can be illustrated by experiences in barley breeding. About 25 years ago there came a demand for smooth-awn barley, for reasons that any one who has shocked or threshed barley will understand. Accordingly, crosses were made between the variety Lion, which had little but its smooth awns to recommend it, and Manchuria, a good barley except for its saw-tooth awns. What appeared to be good, smooth-awn hybrids were developed from this cross, but after they had been grown for some time, they proved to be poor yielders. In seeking the reason, it was found that they were very susceptible to the spot-blotch and root-rot disease caused by a fungus with the euphonious name of *Helminthosporium sativum.* Work was then started by plant breeders and plant pathologists at the Minnesota Experiment Station in attempts to produce varieties with smooth awns, stiff straw, good quality, yielding ability and resistance to spot blotch. Within a few years two varieties, Velvet and Glabron, were developed and distributed. Several years later, however, it was found that they were extremely susceptible to loose smut, head blight and to some parasitic races of the barley stripe organism.

Because of the nature of these diseases themselves, it would have been difficult to foresee this development. Loose smut causes abundant infection only when there is moisture during the flowering period of barley. Furthermore, the infection does not become apparent until a year after it has taken place. And at the time when the breeding work was done, no method was known, without absolutely prohibitive labor costs, of artificially inducing an epidemic in order that the relative resistance of hundreds of hybrid lines could be learned. Such a method has been devised within the last few years, however, and will be of great aid in future work. As concerns head-blight, it was not known, even by the most competent pathologists, that it could cause such terrific epidemics in barley; it was considered primarily a disease of wheat. Then, too, epidemics usually develop only when there is warm, moist weather during the earlier development of the barley kernel. And epidemics did not develop during the years when the varieties were being produced. Perhaps the breeders should be criticized for not having furnished the right kind of weather. They do now. By growing hybrid lines to be tested under huge tents, watering frequently to maintain high humidity and spraying the plants frequently with a suspension of the blight spores in water, artificial epidemics are produced so that the relative susceptibility of varieties and hybrid lines can be determined. But this method was a gradual evolution, involving extensive studies by the Wisconsin and Minnesota agricultural experiment stations and the United States Department of Agriculture, of the head-blight pathogen and the factors affecting its development. Even after preliminary, empirical experiments had shown that plants under small muslin cages were more likely to become heavily infected with head-blight than those outside, what would a guardian of purse-strings have said to a request for funds to construct tents under which to breed barley? The realization that weather had to be made to order in an investigation of this kind was a slow evolution,

just as were the necessary principles on which the breeding procedure must be based. And, unfortunately, many of these principles were learned during the breeding work, or even after it had been done; they were needed beforehand. Surely, if we learn at all from past experience, it must be evident that research should precede practice and guide it.

Nevertheless, head-blight has been very destructive in many regions in recent years, as it not only reduces yields greatly but may also make the barley unfit as feed for pigs, because it makes them violently sick. Therefore the development of resistant varieties is urgent. But no varieties of barley now known in this country seem to be sufficiently resistant. Obviously, then, a search must be made in other countries, an important job for plant explorers. And possibly it may be well to remind ourselves that plant explorers who search for plants in many distant lands are not looking only for the curious and bizarre but often for plant varieties that are essential to the solution of just such problems as the barley blight problem. Their work usually is hard and often hazardous, but it is essential. They must find resistant varieties, which often are inferior in other respects. Then the breeder must cross them with otherwise good varieties and attempt to get the desired combination of characters in hybrids.

The complexities of some breeding programs are well illustrated also by experience with wheat. About 1907 the United States Department of Agriculture and the Minnesota Agricultural Experiment Station embarked on a program of developing stem-rust resistant wheats. Bread wheat varieties were susceptible, but many durum or macaroni wheat varieties seemed resistant; therefore crosses were made between durum and common wheats in the hope of combining the bread wheat character with the rust resistance of the durums. Many of the most resistant hybrid lines were so susceptible to root rot that they were discarded, or the root rot automatically eliminated them. It also was found that there was linkage between the durum character and rust resistance; those hybrids that were rust-resistant also had the quality of durum wheats and not of bread wheats. This was discouraging, and some thought that it would be impossible to combine rust resistance with other desired qualities. Advances in knowledge of plant genetics, however, indicated that there might be "crossing over," that there might appear an occasional hybrid in which the bond between durum quality and rust resistance was broken. The obvious procedure was to grow large populations of hybrid lines. This was done, and finally a few plants in one line out of about 1,000, from a cross between Marquis and Iumillo durum, were found which combined the desired characters of rust resistance with bread wheat characters. From one of these plants the variety Marquillo was developed. However, flour made from Marquillo is so likely to be off color that it is no longer recommended and has been replaced by better varieties.

One of these better varieties is Ceres. The first step in its production was the development of the variety Kota, which originated from some resistant plants of bread wheat found in fields of durum. These plants were selected, propagated, tested, and the progeny finally distributed. Kota appeared very resistant to stem rust but soon proved to be so susceptible to orange leaf rust, to loose smut and to stinking smut that it fell into disfavor. In addition, it had very weak straw and was therefore likely to lodge badly. It was then crossed, at the North Dakota Experiment Station, with Marquis, at that time the standard bread wheat of the spring wheat region. One of the hybrid lines was developed into the

variety called Ceres. Ceres has far stiffer straw than Kota, is in general better wheat, and appeared to be equally resistant to stem rust, and certainly no more susceptible to the smuts and leaf rust than the Kota parent. It was moderately to highly resistant to stem rust and withstood a number of rather severe epidemics very well, but it succumbed completely to the terrific epidemic of 1935 because of a combination of factors that were unfavorable to its development and extremely favorable to the development of certain parasitic races of stem rust.

Better rust-resistant varieties than Marquillo, Kota and Ceres are either made or in the making. All three have rusted heavily under some conditions and have other defects. The production of Marquillo had shown the possibility of obtaining resistant bread wheat types from crosses between durums and bread wheats. But this variety is susceptible to root rots, its flour is low in color score, and it is not always so resistant as is desirable. For these reasons one of its sister selections was crossed with a selection from a cross between Marquis and Kanred, a hard red winter wheat, which is immune from a considerable number of parasitic races of stem rust. This double cross, (Marquis × Iumillo) × (Marquis × Kanred), has resulted in the production of the variety Thatcher, which obtained one type of resistance from Iumillo, another from Kanred, and has the spring habit and high quality of Marquis. So far Thatcher has been moderately to highly resistant to stem rust, but there are indications that it may become heavily rusted under some conditions. Furthermore, it is quite susceptible to orange leaf rust. Therefore it and other selections and varieties have been crossed with Hope and H44, two varieties produced by McFadden as a result of crossing Marquis with Jaroslav emmer, which is resistant to stem rust, stinking smut and several other diseases. As in the case of bread wheat-durum crosses, only a few hybrid lines combined bread wheat characters with the resistance of the emmer parent. But Hope and H44 did. Although they are not good wheats, they have been used extensively in recent years as resistant parents in crosses with better wheats. But another complication has arisen. Both Hope and H44 are very much more susceptible to the black chaff disease than the varieties now grown. This, then, introduces another new problem, especially since there appears to be linkage between the resistance to rust and susceptibility to black chaff. That is, rust-resistant segregates from crosses with Hope or H44 as one of the parents are susceptible to black chaff. Possibly this linkage can be broken, or possibly the disease will not be very important. That remains to be seen. Certain it is that many of the hybrids between Hope or H44 and other varieties usually are almost immune from stem rust. But will they remain so under all conditions?

Hope wheat has rusted heavily, not only in experimental tests in the greenhouse, but also under natural conditions in the field, as shown by Abbott in Peru. And why should it not? Disease resistance, like any other plant character, varies more or less with environmental conditions. The practical question is, how much will it vary under the range of conditions in which the variety is likely to be grown? Hope has varied from virtual immunity to virtually complete susceptibility. Seedling plants are highly resistant to many parasitic races but completely susceptible to some. As the plants grow older, however, they are likely to be resistant to all races, because of a combination of characters which make it difficult for the rust to enter and to develop well even if it does succeed in entering. Then why does Hope sometimes rust heavily? The question has been answered, to a con-

siderable extent at least, by investigations made by Helen Hart. Stem rust does not enter Hope as easily as some varieties because the stomata have a tendency to remain closed much of the time. It takes considerable light to make them open. Therefore if there is moisture on the plant long enough to enable the spores to germinate while the stomata are open, the rust enters. The important thing is to have light and moisture for considerable periods of time. Obviously, this combination is not likely to occur often. While light is required for entrance of the rust, it develops well after entrance only under reduced light intensity, its development being sharply checked in full sunlight, just the opposite of the case with most varieties. Clearly, then, Hope will become heavily rusted only when a rather unusual combination of conditions prevails. There must be abundant inoculum of one or more virulent physiologic races, there must be light for considerable periods while the plants are wet to permit entrance of the rust, followed by lowered light intensity to permit the rust to develop. These conditions must be repeated several times in order that an epidemic may develop. Therefore Hope is not likely to become heavily rusted very often, but it has been heavily rusted and no doubt will be again. It is resistant under more conditions than most other resistant varieties and is therefore extremely valuable; but it is not universally resistant, and this fact may as well be recognized now as later.

Even if the mechanism of resistance of varieties remained constant, their disease reaction might vary greatly because of the existence of parasitic races. Investigations during the past twenty years have shown that there are numerous parasitic races of the cereal rust fungi, the cereal smut fungi, those causing root rots of cereals, and a host of others. In fact, it appears now that most species of parasitic fungi comprise races that may be alike in appearance but quite different in their parasitism. Approximately 150 such races of the wheat stem rust fungus are known. Consequently, some varieties are resistant in some years and in some localities and completely susceptible in others. The variety Kanred was distributed a number of years ago as a rust-immune hard red winter wheat. It was soon found, however, that it was completely susceptible to some parasitic races and that it may rust heavily when and where these races are present. The same is true of the durum wheats. Until about 1923 they were considered highly resistant to stem rust. However, in that year an epidemic developed on them, and the same thing has happened in a number of subsequent years. Whether most durums rust, then, depends on the particular parasitic races present. And to complicate the matter still further, there is some evidence that a variety may be resistant to certain races at certain temperatures and susceptible at others. In other words, environmental factors determine whether certain races can attack a certain variety or not. This whole series of complications, together with genetic and pathological studies on the nature of rust resistance, led to the breeding of varieties with "adult" resistance. This simply means that older plants of some varieties, because of structural or physiologic peculiarities, are generally resistant to all parasitic races under natural conditions in the field, even though the seedlings may be susceptible. This, then, seemed to be the answer to the challenge of parasitic races. Unfortunately, however, "adult resistance" may vary, as already mentioned in connection with Hope wheat.

What has been said about stem rust is equally true of other diseases. The fact that there are so many parasitic races and that the resistance of varieties, even to single races, may vary merely

shows the complexity of one of the most important problems in plant protection, the breeding of resistant varieties. The difficulties have not been magnified. Numerous examples could be given in support of this statement. Many varieties of wheat were resistant to stinking smut, only to become susceptible; some wilt-resistant varieties of flax have become susceptible; some smut-resistant varieties of sorghum have lost their resistance; certain mosaic resistant varieties of sugar-cane are no longer resistant. Nature is not static; it is dynamic. The plant disease problem is not static; it changes. And why should it not change? The pathogens that cause disease change.

Extensive researches during recent years show conclusively that new parasitic races of pathogenic fungi arise through mutation, hybridization and probably through chance assortment of nuclei. That new races arise through mutation is perfectly clear from studies on certain smut fungi; that they apparently arise in several fungi through chance assortment of nuclei seems likely from recent studies in California and elsewhere; that they arise commonly through hybridization in some of the ascomycetes and in the rusts and smuts is proved beyond question. Hybrids have been made between biotypes within a species, between different species and even between different genera. In fact, the union of lines of different sex is prerequisite to infection in the rusts and smuts. While we are breeding disease-resistant varieties of crop plants, nature is breeding new races of crop pathogens. Man probably can keep ahead of nature, but to do so he had better know what nature is doing to checkmate him. To proceed blindly in the dark is not likely to lead to greatest progress. Research must show the way.

It must be apparent, even from the few examples given, that obstacles to the development of resistant varieties are not necessarily insuperable; in many cases they are not, because they already have been overcome. In other cases they are still to be overcome. It is not desired to magnify difficulties and cast a pall of pessimism over breeding as a method of protecting plants. Quite the contrary. The fact is that breeding is the only hope of controlling some of the most destructive diseases. The need for resistant varieties is acute. What it is desired to emphasize is the urgent necessity for an appreciation of the complexities inherent in many breeding problems, for fuller understanding of the needs in solving them, and for wider vision with respect to the scope of necessary researches and their results. In some cases suitable resistant varieties already are available, but in many others there are no commercially desirable ones. Plant exploration may be required; testing and sorting is necessary. The genetics of the crop plants must be studied; the number and parasitic capabilities of parasitic races of the pathogen must be learned; studies should be made to ascertain whether new races are arising; the nature and variation of resistance should be studied; and ecologic studies must be made of the host plants in relation to the disease. Only on the basis of such studies can serious mistakes and disappointments be avoided and permanent progress be made. For it is important to know not only what has happened but also what is likely to happen under certain conditions. Even so, it may be necessary to replace varieties periodically, as commercial requirements and natural situations change.

There has been great progress in plant protection, and the prospective accomplishments are still greater. Emancipation from empiricism will be one of the most significant. This will require more intimate knowledge of crop plants, elucidation of the nature of disease inciters, such as viruses, more detailed life his-

tory studies, finer analysis of the rôle of environmental factors in the development of disease, epidemiology studies to improve predictability of disease outbreaks, vast improvement in specific control measures and more precise knowledge regarding their application. Botanists of many persuasions must cooperate in these studies even more closely and sincerely than in the past.

"The price of a sound, comprehensive national life is in these times widespread and intelligent scientific research." This quotation from Angell is applicable to plant protection, as well as to problems in general. Botanical science can promise man better varieties of crop plants and can show how better to protect them against diseases and other hazards. But to accomplish this there must be provision for basic research, to discover facts and formulate principles; experimentation, to determine when, where and how they can be applied profitably; and education, to incorporate them into practice and capitalize on their value. We need not only fuller knowledge, improved skills, and better techniques, but also a deeper and more widely diffused sense of obligation to science and to society and a determination to discharge it equally faithfully and honestly to both. This statement is platitudinous, of course. But, like many other platitudes, it often is ignored and can be emphasized with profit. And it is not mere parroting of a newly popularized slogan. Many investigators and most teachers were thoroughly imbued with the idea long before attention was focussed on it in recent years. What is lacking in many cases is not the spirit but the substance to enable science to serve society.

There must be much good research, but much of it must be good for something. Only when there is broader realization of the ultimate value of basic research, not only to clarify situations, but especially to provide a reservoir of facts and principles for future emergencies, will it be possible to proceed as intelligently and effectively as necessary in plant protection. If past experience teaches anything, it teaches that the most fundamental research often is the most practical in the end. Plant disease situations continually change, because crops and pathogens and conditions change. New problems continually arise. Only by elucidating principles and accumulating wisdom through research can we foresee possible future developments and prepare to meet them. Apathy and lack of comprehension, rather than antagonism, are the greatest obstacles to research and progress. Many people still have a child-like faith that science can perform miracles. A new disease or insect pest menaces an important crop. The formula is to provide money and demand a miracle. "Miracles of science" may be a good figure of speech, but most scientific miracles are the result of long and laborious search and research, repeated many times. We hear much about preparedness. Preparedness is essential in plant protection, but we had better prepare for the future before it arrives instead of after it is present or past. And preparedness must be based on research.

THE COMMERCIAL-RESIDENTIAL ECOTONE

AS EXEMPLIFIED BY HASTINGS, NEBRASKA

By Dr. THOMAS F. BARTON

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GEOGRAPHERS have adequately discussed as units many rapidly growing towns and cities. In an increasing number of articles writers have also delimited portions of urban areas devoted to a definite economic function. These functional divisions, such as the commercial, residential and transportational, have been treated as to importance and interdependence. Up to the present, however, almost no attention has been given to the description and interpretation of the transitional zones between the functional divisions.

Although the transitional zones between functional divisions are not large, they are often a conspicuous part of the urban landscape. An attempted horizontal expansion of one functional division means a conflict with the use already established in the invaded area. The function giving the greatest economic returns usually encroaches upon and replaces a less productive one. Within the zone of conflict, a landscape is produced which represents neither of the two divisions, but, rather, represents a result of a combination of their characteristics.

These transitional urban zones or areas vary in size, being large and very conspicuous, usually in cities of over 50,000 inhabitants, and smaller and less well developed in cities of 10,000 to 25,000 inhabitants. In some towns, only a few features of a changing zone are evident. However, where the transitional zones are of sufficient size to be delimited because of their distinct landscape character, they become a subject for discussion.

ENLARGEMENT OF HASTINGS' COMMERCIAL CORE

In a reconnaissance survey of Hastings, one's attention is called to the fact that the commercial division of the city is expanding horizontally toward the north and west. The direction of growth is indicated by the new commercial structures, the residential structures utilized by retail or service businesses, and the isolated houses which stand surrounded by commercial establishments. The extent of the horizontal expansion becomes conspicuous when one contrasts it with the slight vertical expansion, as shown by the low profile of the commercial core. For example, the business district contains only two buildings of more than five stories; the others are buildings of two stories or less. Moreover, the vigor of the commercial encroachment upon the residential division stands out in bold relief when contrasted with the unoccupied lots near the heart of the commercial division.

These idle lots are found here for several reasons. They are in most cases held by the railroads or citizens for speculative purposes. Also, taxes are levied on property and if a lot is vacant the tax is low. Some of the lots formerly contained buildings, but these were torn down and new buildings have not as yet replaced the old ones.

Therefore, in spite of slight vertical expansion and vacant land near the heart of the city, some establishments now occupy and others are moving into structures formerly used as private residences. The residential function is forced out and replaced by a commercial

one. This change brings a transformation to the physiognomy and the structure of the individual building and the entire block. Thus there is a tension zone or an area of "no man's land" between these two economic divisions, the commercial function steadily winning as it encroaches upon and absorbs the adjacent residential area until the movement is blocked by some cultural or physical feature. Since geographers have not coined a term for this land utilization area with its distinct landscape, the writer suggests the term "commercial-residential ecotone."

Origin and Use of the Word "Ecotone"

"Ecotone" is a Greek word meaning tension-zone or a battle front along which two forces are endeavoring to occupy the same space, but with the final result that one wins the struggle and advances over the conquered territory.

Plant ecologists use this word to designate the area in which a struggle is taking place between two plant formations as one tries to retain an areal space while the other fights to gain new ground by encroaching upon its occupant. For example, the buck brush from an erosional ravine tends to spread into the prairie occupying the interfluvial area. This plant sends out rhizomes, which reach several feet beyond its border into the prairie's area. The new buck brush plants in turn send out roots, and by continuance of this process the brush forces the edge of the grass to recede. The area which is being contested is a transitional zone occupied by both forces for a period of time until the advancing force overcomes and eliminates the defending one. However, once the encroaching force completely occupies the area, the former contested ground becomes the site of the invading plant and is no longer a transitional zone or ecotone. The ecotone is only the zone of competition.

In the economic battle, herein set forth, the contestants are, on the one hand, the commercial and, on the other, the residential divisions. For this reason, the term commercial-residential ecotone is used.

The Hastings Commercial-Residential Ecotone

Description and Interpretation: The commercial-residential ecotone of Hastings occupies an area which forms a pattern resembling roughly an imperfect ziggarut with its highest point at the intersection of St. Joseph Avenue and Sixth Street and its base resting on the alley between Third and Second streets (see Fig. 1). This block-like form is due to the rectangular arrangement of the streets and lots prevalent in most American cities, but which are not typical of most European ones. The serrated boundary line is representative of an ecotone, since the encroachment of business establishments upon the residential area results in changing the functions of lots, but not of complete blocks.

Theoretically, the horizontal growth of a commercial division over a level terrain without cultural or physical barriers should be radial. If a line were drawn connecting the tip of each step in the ziggarut-like pattern, an imperfect semi-circle would become evident. The radial pattern on the north is produced by an expansion which has not been interfered with by physical or cultural features.

The ecotone does not completely surround the commercial division of Hastings. Moreover, such a phenomenon may never develop on the southern edge of the business district. Nearly all the light retail and service establishments are located north of the Chicago, Burlington and Quincy railroad and west of the St. Joseph and Grand Island lines. Consequently, one would expect any new business of this type to locate in juxtaposi-

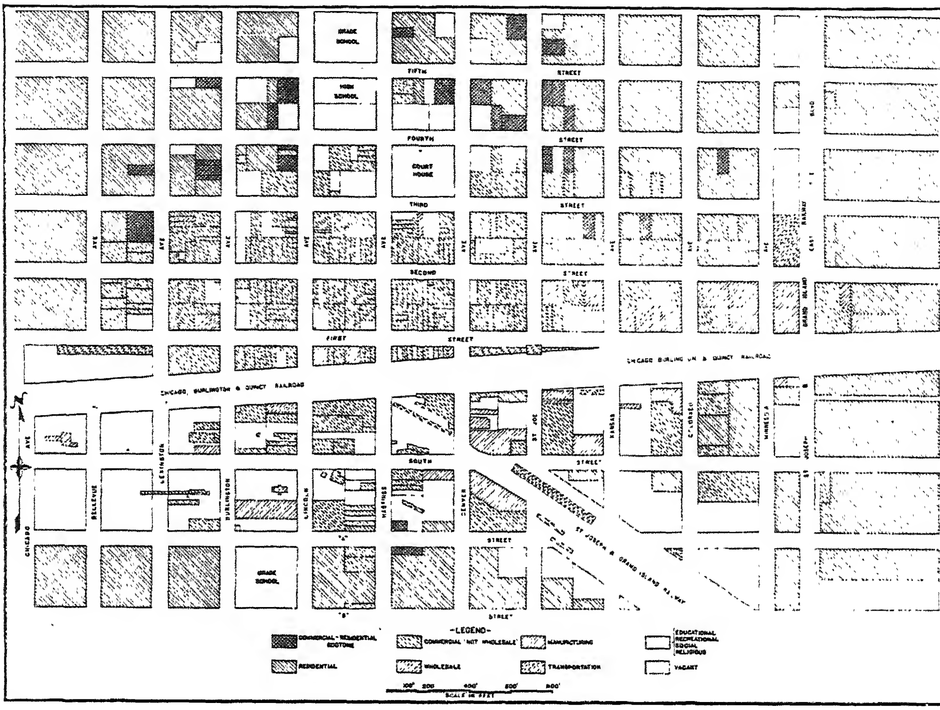


FIG. 1. THE BUSINESS DISTRICT, HASTINGS, NEBRASKA

tion to the old. Approximately 75 per cent. of the urban population is on the north and west side of these tracks; thus, the greatest part of the urban markets are also found here. The commercial area south of the tracks is not esthetic in appearance, because of junk yards and farm produce stores. Light retail and service businesses generally avoid such an area.

Moreover, the heavy retail and service establishments, found in the southern part of the commercial core, are not the type that makes use of residential structures. They consist in the main of garages, filling stations, lumber yards, implement houses and farm produce stores.

The ecotone area contains a number of residences which have been converted into apartment and rooming houses. This conversion will likely continue on the inner fringe of the residential area surrounding the northern part of the commercial division because: (1) the residential area north of the commercial division excels that to the south, (2) the greatest employment is found north of the Chicago, Burlington and Quincy tracks and therefore the residents to the north would be nearer to the place of work, and (3) the railroad tracks and the long freight trains act as barriers.

Although the numerous cultural features listed here prevented an ecotone from developing south of the business district, the decaying residential border adjacent to the northern side of the commercial division enables an ecotone to develop. This area contains old houses, many of which were constructed during the first decades of the town's growth (1872–1892). A large number of the residences are of old architectural design

and lack modern conveniences. In many cases exterior and interior remodeling would exceed the value of the building.

Furthermore, this residential periphery adjoining the retail area on the north has become less desirable because of the change brought about by the business atmosphere in the last two decades. With the coming of paved streets and the extensive use of trucks and automobiles, noises, dirt, odors, heavy traffic, fumes and gases have vastly increased (see Fig. 2).

Several economic forces are instrumental in stimulating the migration of retail and service establishments. Marginal businesses have been influenced by some profitable competitors to migrate farther and farther from the commercial core in order to cut cost of operation. These migratory establishments evade the high rents[1] demanded in the core of the business district. They usually are marginal producers or belong to a class of business which does not yield the greatest net returns, and therefore can not afford to locate in choice sites. As a rule, commercial land utilization gives greater net returns than residential utilization; therefore, the residential use gives way with little resistance before the increasing pressure of encroaching businesses.

[1] The writer is unable to say whether rents were excessively high in the business district or not but was told by the people in charge of businesses located in houses that rent was too high for them to occupy commercial buildings in the business core (interviews, summer, 1933).

The peripheral retail and service establishments in Hastings are laundries, small grocery stores, repair shops, tailor shops, paint, print and radio shops, doctor's offices, beauty parlors, rooming houses and remodeled residences with apartments. These businesses are easily adjusted to old residential structures. Shingle signs on porches, billboards in yards or large paint signs covering the front windows indicate that a former residential structure is now performing a commercial function (see Fig. 3).

A city block transformed in function is also transformed in structural appearance. In the process of change, the wooden structures are replaced by brick buildings. Trees and lawns disappear. Since the price of land is high, all ground must be utilized, consequently detached structures are replaced by buildings closely constructed and forming a solid

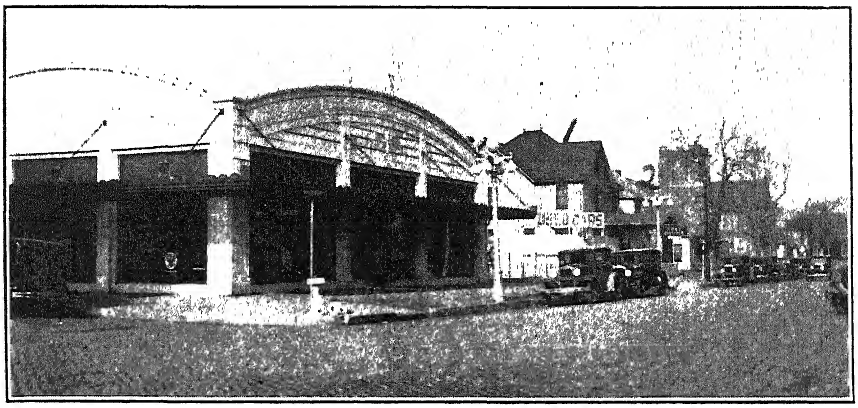


FIG. 2. A NEW COMMERCIAL DISTRICT

A GARAGE AND A USED CAR YARD HAVE MADE THIS BLOCK UNDESIRABLE FOR PRIVATE RESIDENCES. HOUSE No. 1 HAS BEEN CONVERTED INTO A TOURISTS' INN; No. 2 IS DILAPIDATED AND EMPTY; No. 3 IS A BEAUTY PARLOR.

FIG. 3. BUILDING SERVING A DUAL FUNCTION

THE FIRST HOUSE WITHIN THE ECOTONE AREA SERVES AS A HOME AND BEAUTY PARLOR; THE ADJACENT HOUSE IS A RESIDENCE; THE THIRD HOUSE CONTAINS A CLEANING ESTABLISHMENT.

row along treeless, lawnless and often auto-crowded streets.

Manner of Encroachment: The encroachment of light retail and service establishments with advancements made along certain streets, or lots in one block, takes place along a serrated front. The advancing commercial uses invade a certain district, and, offering a greater net income, either replace the residential function, or the commercial and residential one may share the same structure for a period of time. The buildings first invaded are usually of least residential value, are in a strategic business location, or are occupied by persons engaged in a certain type of business. Since some residences in a block are of more value than others, and their owners wish to use them a few more years as homes, the migratory enterprises do not present an even advance.

Once commercial establishments enter a few buildings in a block they act as a nuisance and become wedges for further commercial development. Consequently, as the number of structures devoted to commercial purposes increases, the remaining residences depreciate in value. Moreover, as the desirability of a location for residential purposes decreases the taxes become proportionally higher and residential value decreases; therefore, the owners are forced to liquidate and sell their property or change its use.

The residential utilization of land is not an intensive one when considered from the standpoint of net income. It is apparent that a lot in the residential area in juxtaposition to the retail one has its value increased as the commercial core expands horizontally in its direction. The failure of the residential function to resist the commercial one is due primarily to the residential use being the lowest income-producing utilization of urban land.[2] As a city's business district moves in any given direction, the value of blocks and lots for commercial purposes in its path is greatly enhanced. Thus, in time, the residential function yields to a more remunerative use.

In the ecotone, as a matter of economy, the residential structures are often used for commercial purposes. The cost of supercession from a poor function to one bringing a larger net income is high. Necessary factors to be considered here are: "The direct and indirect cost . . . of service units in the present improvement which must be sacrificed for the new improvement, the expense of removing the present improvement, and the loss of income suffered from the time

2 H. B. Doran and A. G. Hinman, "Urban Land Economics," p. 522.

when the present improvement is vacated until the new improvement is in full use.''[3]

Establishments found in the ecotone do not have an income sufficient to make possible the destruction of old structures and the erection of new ones. In Hastings, these establishments are marginal economic producers. High rents made them unprofitable, and merchants were forced to move from the center of the business district to this transition zone. Some of the enterprises, however, developed in the area, and came into being because of the economic opportunities offered. Therefore, the profits of these migratory establishments do not warrant the destruction of the present structures.

In the early stages of encroachment many of the residential buildings serve a dual residential and retail function. In this manner, the cost of supercession is reduced to a minimum. Thus, a saving is made by extending the physical life of these structures beyond their functional use rather than immediately razing the structure because economically a change in function is desirable. The process of change is a gradual one, without abruptness and not susceptible to large financial failures. As the establishments prove successful the increase in volume of trade necessitates the use of the entire building. Once a business is thoroughly established on a paying basis, capital is accumulated and the old residence is replaced by a new commercial building.

Existence of Commercial-Residential Ecotone

The commercial-residential ecotone is not a peculiarity found only in Hastings, Nebraska. Similar transitional zones with their characteristic features may be found in many growing cities. This phenomenon is believed to be typical of growing cities where the area occupied by commercial divisions has been surrounded and limited by residential ones of an earlier period in the city's history. In some cases, the city may have developed to the extent that the surface area is no longer adequate to accommodate the increasing commercial establishments responding to the city's growth in trade.

In most cases, the commercial core expands gradually and the migratory establishments invade the residential area as the city's volume of business increases. Expansion must be either vertical or horizontal. Unless it is checked by salient physical features, public buildings or an ordinance zoning law, expansion is usually horizontal until distance from the center of the commercial core hinders further growth.

Encroachment of this type is conspicuous and has been observed by the writer in Peoria, Illinois; Memphis, Tennessee; Kenosha, Wisconsin; Lincoln, Nebraska; and other cities, but their ecotone areas have not been studied in detail as in Hastings, Nebraska.[4]

Because transitional zones do exist between the commercial and residential divisions of some cities and because these zones are large enough to be delimited and have a distinct landscape, the writer believes that these areas are worthy of geographic treatment. Since a name for these transitional areas does not exist, the term ''commercial-residential ecotone'' is suggested.

[3] *Ibid.*, p. 213.

[4] Hastings, Nebraska, was mapped in detail by the writer during the summer and fall of 1933.

THE HUMAN SIDE OF SNOW

THE SAGA OF MOUNT ROSE OBSERVATORY

By Dr. J. E. CHURCH

METEOROLOGIST, NEVADA AGRICULTURAL EXPERIMENT STATION; DIRECTOR, MOUNT ROSE WEATHER OBSERVATORY

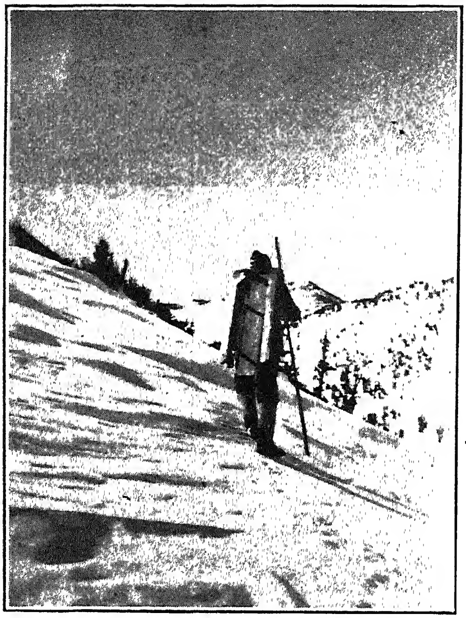
LAST year the reminiscing columns of the press recalled the fact that 40 years ago two men from the University of Nevada climbed the bare peak of Mount Rose, 10,800 feet, overlooking Lake Tahoe, on New Year's Eve. The same news columns have now announced that this past September the leader of that party has organized the International Commission of Snow at Edinburgh. Thus in the space of less than half a century a trip made solely in love of winter nature has given birth to snow surveying and to a world organization whose central purpose is to study the scientific and human aspects of snow and ice, now designated as a new field in hydrology and by some as a new science with the forbidding name of cryology (the science of cold).

Snow surveying may have originated in Europe, but no trace remains. It started anew in Maine in 1900, under the leadership of Charles W. Mixer, to know the prospects for filling the storage lakes of the upper part of the Androscoggin Basin from the snow cover for a year-round regulation of flow and to give a warning of the spring runoff or flood on the lower part of the river. This pioneer effort still survives. Mixer's object was to determine the water content of the snow, which in terms of depth only is an elastic substance incapable of accurate measurement.

Snow surveying started anew in New York in the experiments of Robert E. Horton to create a weighing snow-sampler in the study of the physics of snow.

But somehow the originality of the West and its need of water caused the Mount Rose method of snow surveying to spring up independently and persist against inertia and opposition until it has covered the West and returned to the East, where it now covers the Adiron-

ERECTION OF MOUNT ROSE OBSERVATORY, 10,800 FEET. ARRIVAL OF FIRST PACK TRAIN AT SUMMIT.

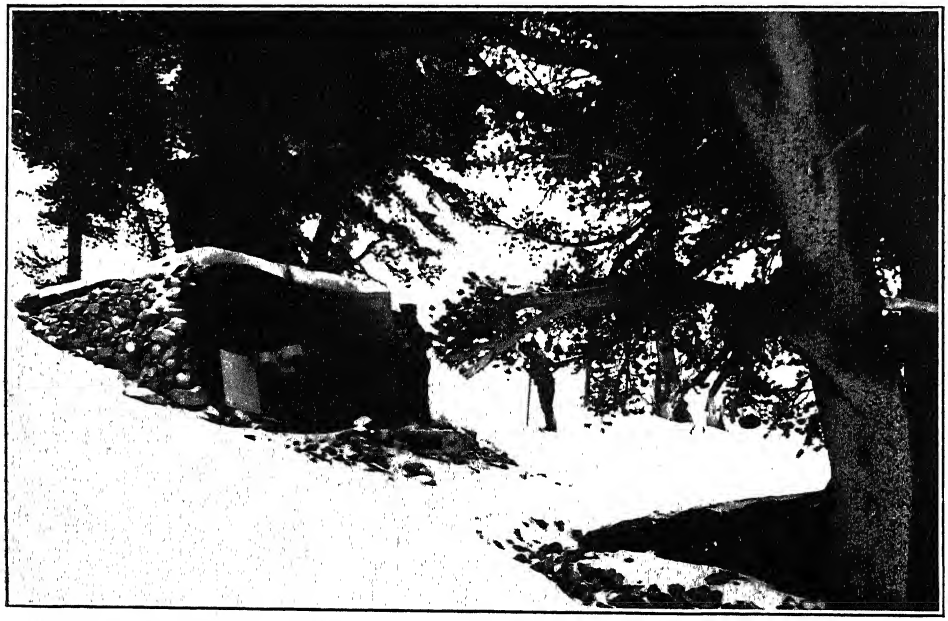


OUR SLED AND BASSWOOD WALKING STICK.
SLOW UP, FAST DOWN.

dack Region of New York, the Connecticut Basin of New England, portions of Canada and west central Newfoundland. But its route has also been westward to far Australia, where the state of Victoria is generating power from snow. India and Argentina are completing the world's circuit, while Greenland and the Alps have become laboratories in glacier study.

The story has earlier been intimated in the *Scientific American* under the title, "The Snow-Surveyor of the Sierras," January, 1933, by the author of "Eiley Orrum," but its details have become a saga of mountaineering, which the writer and leader of that midwinter party desires here to relate.

All movements grow slowly. The whole undertaking started unexpectedly in the Sierra Nevada in December, 1895, in defiance of a sneer at my proposal to make a belated ascent of Mount Rose after the snows of winter had fallen.



MAN-TALL REFUGE CAMP ON MOUNT ROSE, 9,000 FEET.
SLEEPING BAG TREE AND ORIGINAL REFUGE HUT IN RIGHT FOREGROUND.

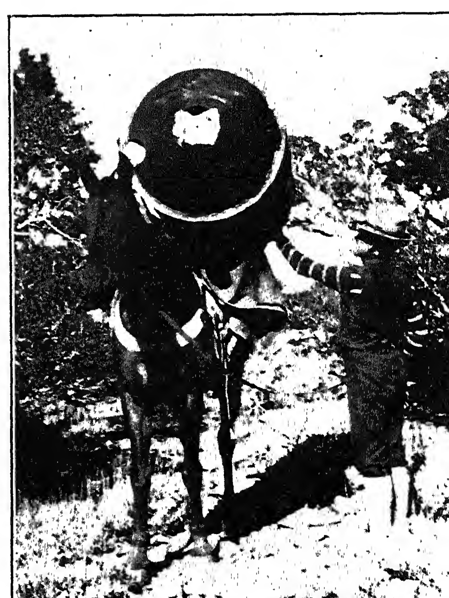
ORIGINAL REFUGE HUT, 9,000 FEET. CRAWLING OUT.

We had nothing but rubbers and one pair of webs for two, and the mountain rose a mile above its base. The route then laid out has remained the usual route to the present day.

After returning from Germany in 1901, where winter resorts were maintained on the lower peaks, Mrs. Church and I ascended the Sierra to elevation 9,000 feet, where we lived for a week at Christmas in fragments of cabins without heat, except for cooking, and roamed in a world so far removed from our own that only the soft whistle of the distant locomotive penetrated the stillness.

A fifteen-hour ascent of Mount Rose, at the apex of our range, was made with only the starlight to guide us back along the cornices of snow. Each evening we lighted a tiny star from some dead pine to assure the anxious watchers in Reno that we still were there.

The adventure spirit was now taking fast hold. I had had belated dreams of



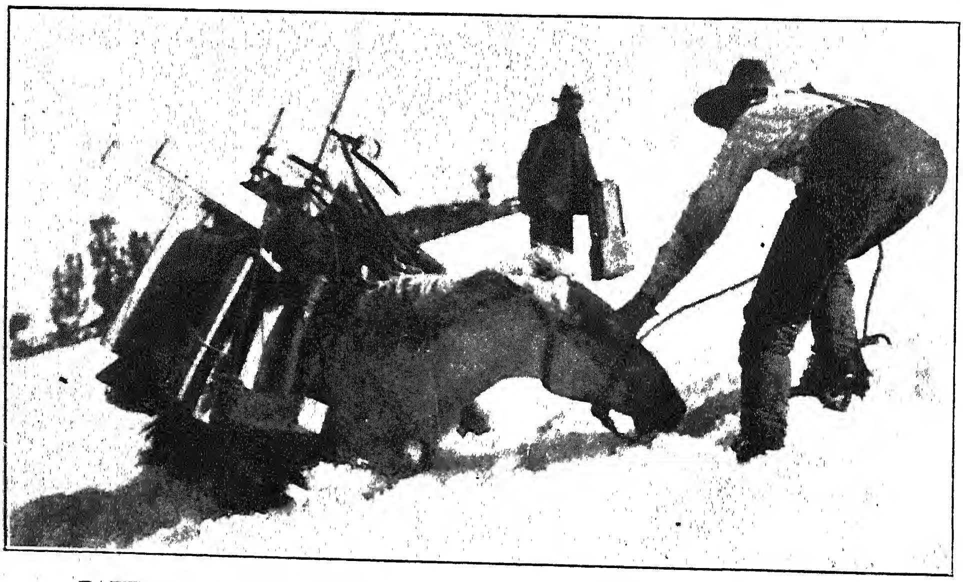
PRECIPITATION TANK ENROUTE TO SUMMIT.

FIRST INSTRUMENT SHELTER ON MOUNT ROSE.

the Arctic, but realized that now I must find my enthusiasms in my own back yard. Only one man in California had so far ventured into the winter wild. He was Bolton Coit Brown, of Stanford. At that time I was ignorant of the great adventure of John Muir up Mount Shasta and decided to dynamite the Californians into setting foot on snow for the sheer joy of it.

So in 1906, in midterm time when the snow was deepest, I persuaded G. F. Marsh, of Lone Pine, to guide me up the east face of Mount Whitney (altitude 14,501 feet) to make the highest winter ascent possible in the United States. We had a week of vision over the "Land of Little Rain" and blue Death Valley from out the skirts of the storm playing over the crests of the High Sierra. We mounted to 13,300 feet, where the monument on Mount Whitney could be seen just overhead, but stopped when ominous cracks opened in the snow above us and rocks dislodged by our feet fell with a sickening echo from the cliff on which we stood.

Three utterances were spontaneously



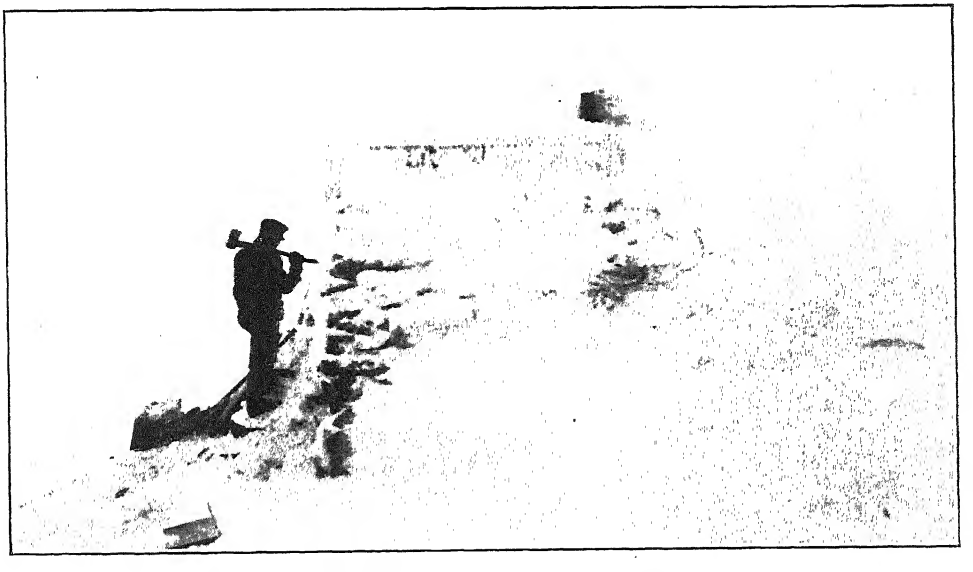
TAKING TINY INSTRUMENT SHELTER TO SUMMIT OF MOUNT ROSE. "BILLY'S" THIRTEENTH FALL, THE AUTHOR AT BILLY'S HEAD.

born on this trip: "Tell them I died happy," a gay retort to a worried colleague, who asked for some last message if I failed to return; "Church, take no chances," which echoed in my ears from my trusting university president, who let me go despite public opinion; and "The call of the wild is strong but the home call is stronger," forced reluctantly from me when on our belated return I saw a tiny figure in white, the wife of my guide, with a baby of six weeks, gazing from the gate into the night at the silent hills into which we had vanished.

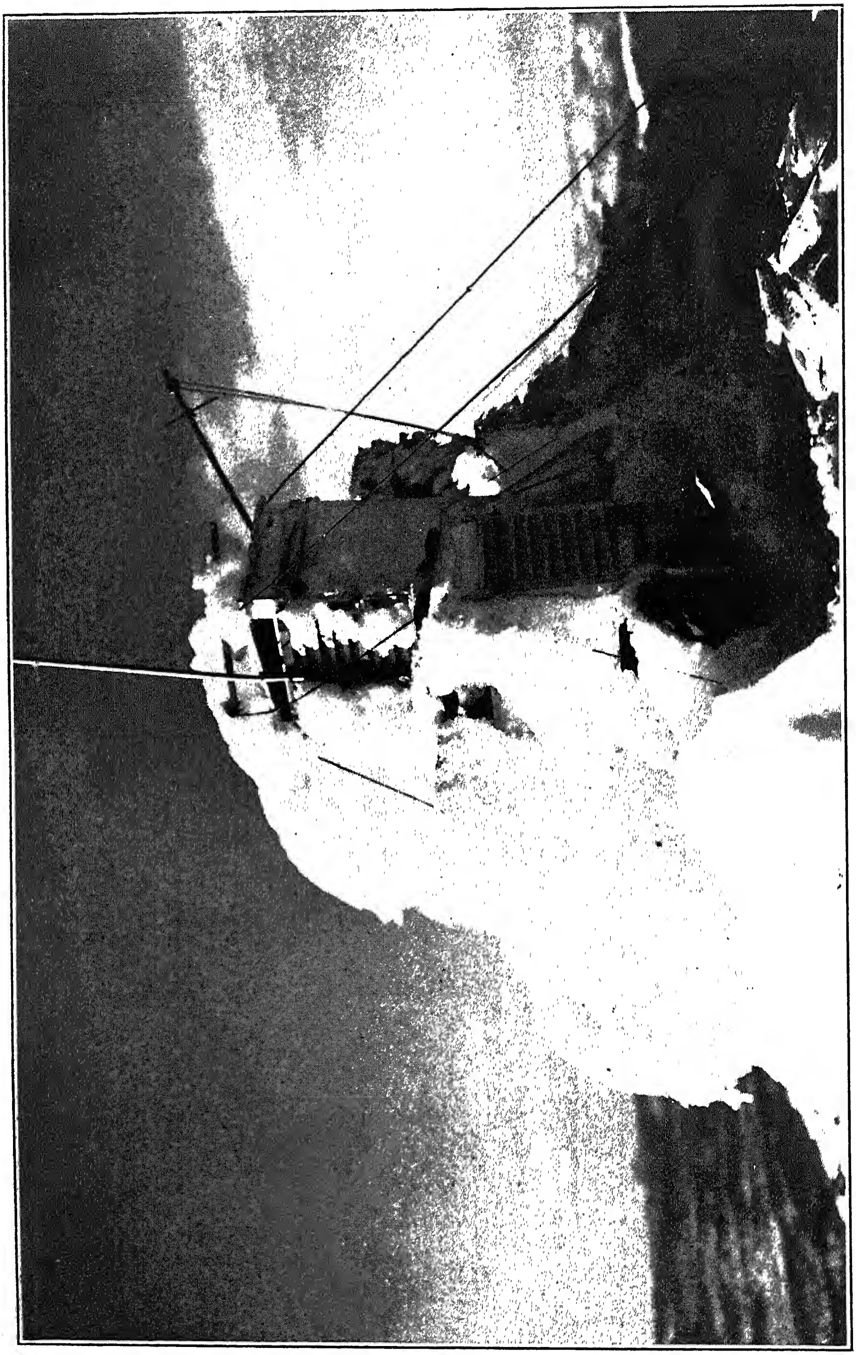
Such was the background against which Mount Rose Observatory was born. I had gone to the hills for pictures and pleasure, but to the public I was merely a great fool. So the humanist decided to become a scientist and a "hero," yet still take his pictures on the side. Now every one goes to the winter hills—some even in oxfords—and heroism has vanished. When my scientific work is rounded out, I hope to return to my pictures with the public's full approval. Thus tradition slowly changes and new view-points and progress are attained.

MOUNT ROSE OBSERVATORY IN ITS FIRST WINTER.

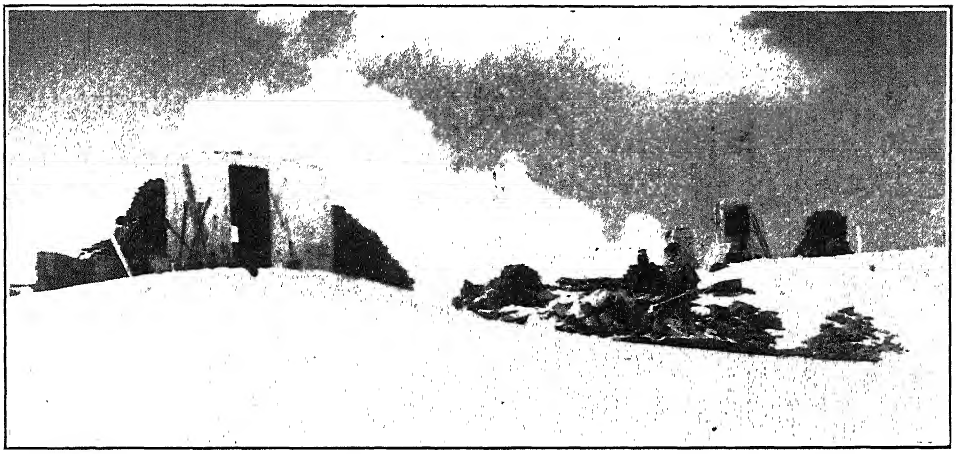
Two great experiences stand out in this



A WINTRY DAY ON MOUNT ROSE.



WRECKED BY ICE FEATHERS.



SUMMIT OF MOUNT ROSE FULLY EQUIPPED.

quarter century of toil and fullness of life. First, the abundance of knowledge that nature will pour into your lap if you will come within her reach. Second, the zest of adventure. In the first, we had no training other than that required of an Arctic explorer, *viz.*, the willingness to endure and the desire to observe. Our special training had been in the classics wholly. In the second, a self-selected group of adventurers (many dropped promptly out) became devotees to the adventure and by their man power put over the task that would have crumpled one man working alone. However, this lure almost brought destruction to the work, for when the federal inspector once accompanied the party to Tahoe, in which for his sake the trip was confined to cruising and pointing out the snow courses from far below, he too caught the germ as he handled the boat's tiller, but considered the project merely a summer outing at government expense.

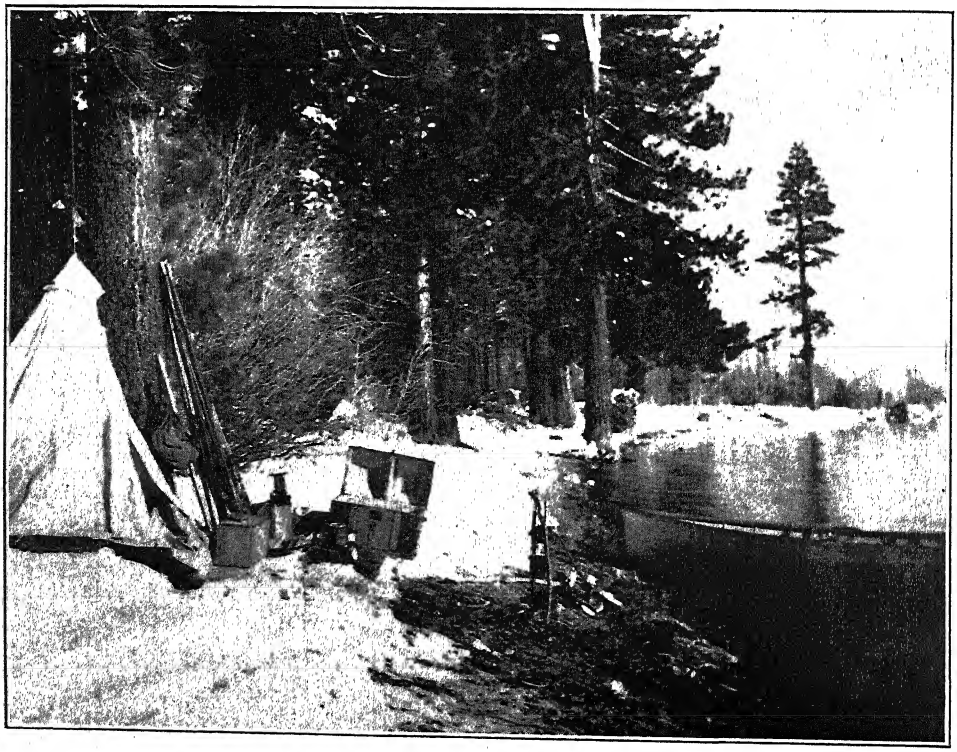
At the time of the trip to Mount Whitney, winter temperatures at high elevations in the Sierra were wholly unknown, except for a minimum reading on Mount Ritter, I believe, from a thermometer cached over the winter in the rocks. On my return, I offered to take maximum and minimum temperatures on the summit of Mount Rose every month for a year if instruments were furnished. They came promptly. A tiny instrument shelter was taken on a saddle pony over rotten snow to the summit.

A minimum reading of zero in August —false but at that time not explainable —started the Associated Press to comment and the scientific world to take interest. A thermograph with time range of ten days was installed. Every two weeks, irrespective of the weather, a party made the ascent to bring down the record. Sleeping bags were hung from a pulley on the limb of a giant alpine white pine at 9,000 feet, and here the members spent the night and split— one going alone up the wild summit, while the other remained in reserve, with instructions to follow in case the other had not returned in four hours.

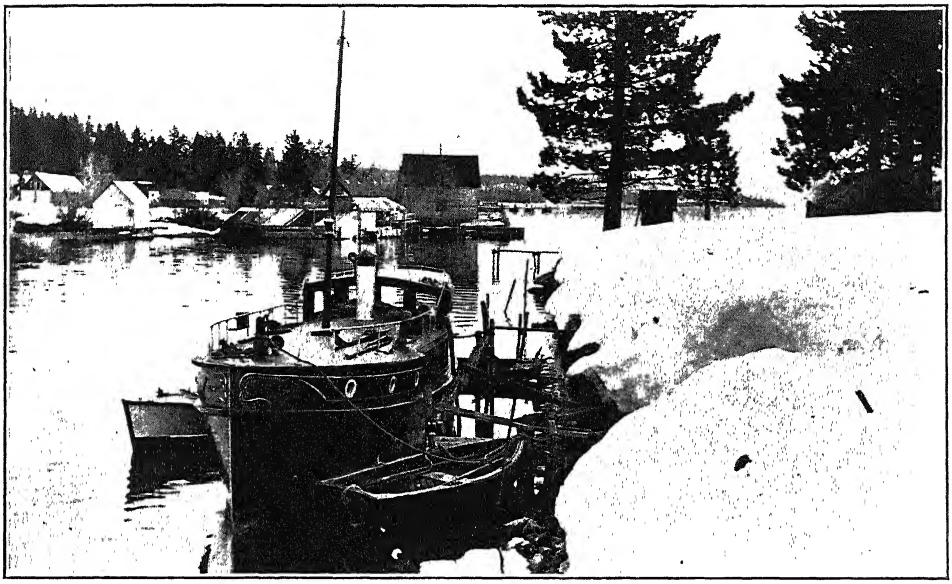
We found nature a genial though austere friend if we heeded her moods, but relentless if we were heedless. Thrice in one week we struggled to gain the record. The first party spent the night in an open grave (for it so looked) dug in the snow to avoid a gale of 70 miles at zero temperature. But though they fought their way to the summit,

they were powerless to remove the tiny record sheet from the instrument and were forced to hold their hands over their faces to keep the latter from freezing. Then I started alone to retrieve the "disaster," threading my way in dense fog along the ridges and sounding the canyons by my voice. But the gale sprang up a second time, carrying the soft snow into the air in density and blindingness like flour in an overturned flour mill. So intense was the gale that my basswood walking stick, whose ends were held firmly by the snow and my clenched hand, vibrated like an aeolian harp. Suddenly a crack opened in the clouds through which I discerned distant hills and my whereabouts. I had wandered into the wildest part of the mountain. To quiet jaded nerves, I rode a sled at full speed down a thousand feet and mounted my pony for the 15-mile trip home. As I did so, the mountain cleared invitingly. The forecast I had followed had been twenty-four hours too early. Two days later the original party made the ascent in comfort, even leaving their coats behind.

Unexpectedly, the Adams Act for agricultural research was passed by Congress and $500 was available if it could be used within three months. Out of this came Mount Rose Observatory, carried up the mountain on pack horses over the untrailed rocks. So valuable did every stick become that silver dollars laid edge to edge over the surface of the building could not have compensated for the physical effort if built by hirelings. It had been a labor of enthusiasm without



OUR ROWBOAT AND SNOW SURVEY PORTABLE CAMP ON TAHOE.
TAHOE NEVER FREEZES.



CABIN CRUISER, "MOUNT ROSE," IN HARBOR.

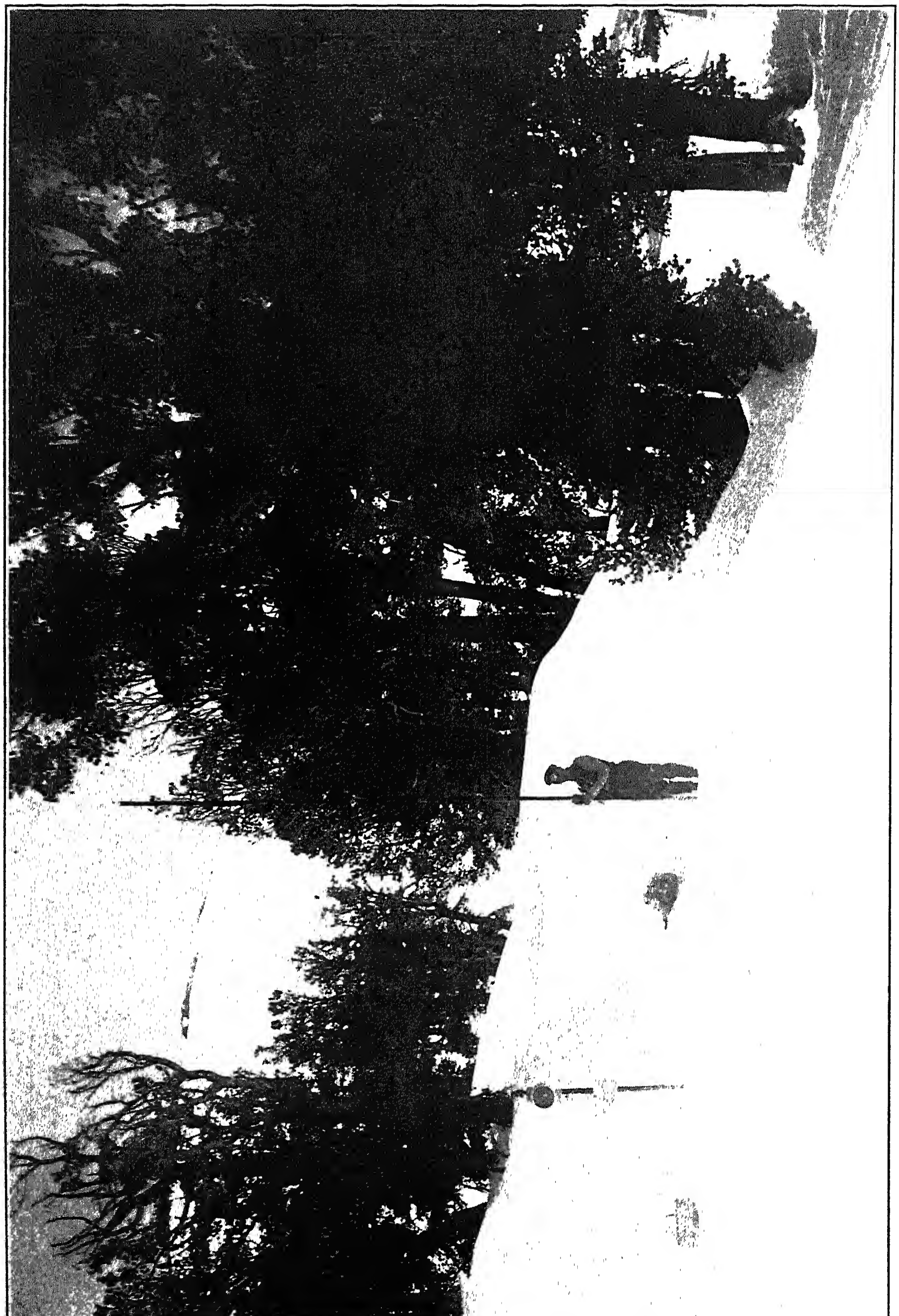
money and without price, with the motto dormant in our thoughts: " 'Fools rush in where angels fear to tread' and are generally successful."

Here again nature was exacting but merciful and lavish of her grandeur. Windvanes, masts, door, electric cables had to be rebuilt to avoid the effect of frost feathers, or lightning that would take bites out of the anemometer cups or steal into the building to set it on fire.

So wild at times was the gale that it would lift me up but promptly allow me to settle gently to the rocks like a stone in a stream, or create such a vacuum above the observatory that the roof would begin to lift from the released pressure within, while the barometer pumped wildly in response. At such times the descent of the mountain became a pleasant swim by lying forward upon the wind and pushing with our feet.

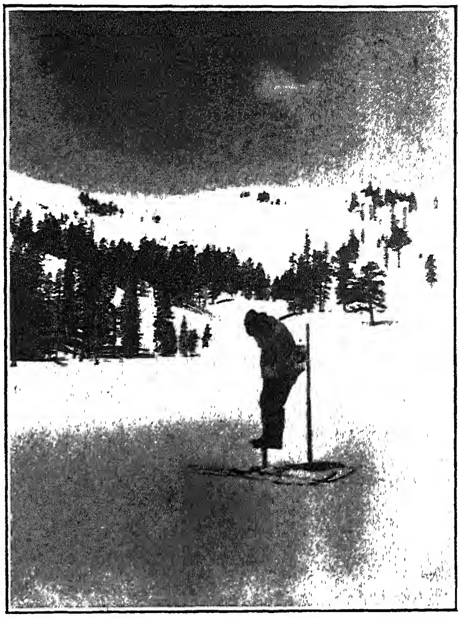
The Refuge Hut was next built at the site of the sleeping bag camp below. At first, a low sandbag hut three men wide and half-a-man tall. A cooking lamp and an immense rabbit skin blanket constituted the furniture. If the dog accompanied the party, he must be the pillow. So close were the quarters that a wood rat once had to fight his way through the tangled hair of my companion to escape from his hole. Here we could lie in comfort (once for 36 hours) while a storm was wearing itself out.

To feel and act like a human, a man-tall hut was next erected, again of sandbags and tar and canvas. A facing of rocks on the windward side protected it from erosion by snow and sand. This hut became the center of our snow surveying, to which we turned in our later study of the effect of mountains and forests on the conservation of snow. Here in comfort we outlasted gales that would have overwhelmed human life if unprotected. One of these left a fin of snow impinged on each tree trunk. In one gale, one of the boys rose up in bed to unhook his trousers from a rafter, remarking when quizzed, "I want my pants if this roof blows off."



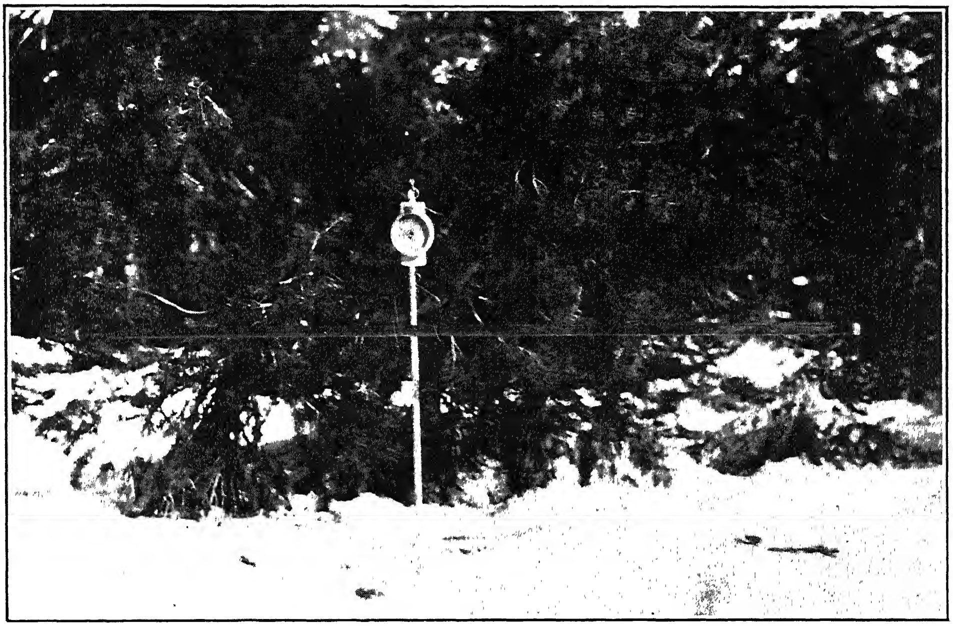
SNOW SAMPLING AT TIMBERLINE ON MOUNT ROSE. THE SNOW IS AS DEEP AS THE SAMPLER IS HIGH.

Enthusiasm begets enthusiasm. The foreseeing college president was urging us on. Our studies of timber and snow, for which the Mount Rose snow sampler had been developed and snow surveys inaugurated, had now been extended to Tahoe, where a never-freezing lake surface and shore line of 72 miles gave access to various types of mountain slopes and forests. Here with rowboat and tent we developed physique, exercising our arms at the oars one day and our legs on the snow the next. The basin became far more accessible than in summer and far more beautiful. Pyramid Peak, Tallac and Freel led us into the depths and heights of the range. The rowboat became the lifeboat tender of the frail motorboat *Skidoo,* which had originally been a boy's pet. Then for fear the motor would fall through the bottom in midlake, the cabin cruiser *Mount Rose* was built to anchor on any shore and ride most gales, however rough.



DRIVING THE SAMPLER IN DEEP SNOW.

The seasons were heavier in those days than in these. Tahoe had risen in 1906–07 a foot and a half above its outlet



WEIGHING A SNOW CORE NEARLY 20 FEET LONG TO DETERMINE WATER CONTENT.

dam. Natives talked of the flood. The heavy year of 1910–11 came with its menace and fear. The Sierra Pacific Power Company begged the use of our snow data to determine how much moisture was latent on the watershed. Thus was born the forecasting of streamflow.

A lake is the least likely spot to begin such a project, for it fluctuates too much to reveal underlying principles readily. But nature was again kind and the relatively heavy winter precipitation of snow in the Sierra as compared with the summer precipitation of rain gave us a preponderant factor with which to work. Luckily we rejected the quantitative measurements usually applied to rainfall and reduced both the snow cover and lake rise to percentage of normal. Then it was quickly seen that the winter snow in percentage of its normal equaled that of the summer rise of the lake. Rivers followed the same rule but more closely. Furthermore, the snow cover was seen to be approximately uniform for long distances along the range.

But divergence crept in—in 1915–16 a divergence of 50 per cent. at Tahoe—and the irate impulsive Southern project manager damned the experiment as a failure. But Major Norboe, chief assistant engineer of California, who was looking for a method while our method was looking for a patron, calmly remarked, "Nature must have butted in." Three years or four of "watchful waiting" and praying that nature would repeat the trick revealed that nature's withholding her spring rain would reduce our expected runoff by 50 per cent. of normal in lakes and 25 per cent. in streams.

The work inevitably spread. The Sierra became a gigantic laboratory filled with alluring vistas of broad principles and individual though minor problems. The Colorado, Columbia and Bow River systems were investigated to determine the feasibility of snow surveying and streamflow forecasting there, that no problem might escape. Even precipitation and runoff on the Continental Divide were drawn into the vortex of discussion. The playful charge was made that we were trying to annex the world. Such is the penalty of a lure.

But snow surveying became a football game of opposing forces, one force being its own seeming vitality and emergency patrons, the other force seeking to close out an impracticable venture. The continuity of its life was due to Major Norboe, of California, and Governor Emmet D. Boyle, of Nevada, and the water users of the latter state. Times have changed. The forecasts of runoff are given a credence that brings fear of error rather than satisfaction to the forecaster. Economic life or death has at times hung in the balance. Adventure is being taken out of snow surveying. The courses are now measured at the base of the highest peaks, and some snow survey systems involve 100 miles of mushing. Cabins, some with Santa Claus chimney entrances where the snow cover lies deepest, form places of refuge and rest. A morale of persistence has been built up. No party returns without its measurements, and these are carefully made. Forecasting has now passed mainly into other hands, but continuity is assured. Old survivors are few. Of these, the most trusted has just been buried beneath the snow of his beloved Tahoe—Bob Watson, tavern guide, who joined the snow survey when others failed. His sampler, like a trusted sword, lay ready on the porch for the waiting survey as his life ended.

The infancy of snow surveying is now past. The National Research Council through the American Geophysical Union has made the hydrology of snow one of its principal projects, and a com-

mittee of snow has been organized covering the entire snow-bearing portion of the United States and its chief watersheds and representing every phase of snow from conservation to removal, from forecasting streamflow and floods to announcing the ideal places and conditions for winter sports.

At the urging of the Western states, Congress has appropriated funds and authorized a Federal-State Cooperative Snow Survey System there in charge of the U. S. Bureau of Agricultural Engineering. Under the impetus given by snow and floods this past winter in the East, Congress is passing legislation to impound potential flood waters at the heads of the streams. To aid in their better control, snow surveys now centered there will inevitably spread to cover the entire north Appalachian region.

To permit the extension of the snow survey idea under world organization, the International Union of Geodesy and Geophysics through the International Association of Scientific Hydrology has authorized the formation of an International Commission of Snow, which again through inherent vitality and opportunity has already expanded to include every phase of snow and ice from the evaporation sunpits of the Andean snows to the ice caps of the Polar regions. Practically all the snow countries of the world have joined and the members are world leaders in their subjects and several are headliners. But herein is another saga worth telling later.

As these lines are being written, a request has come from the British-American Himalayan Expedition for a snow sampler to use in connection with its work, thus showing the turn that has come in foreign view-point. The *London Graphic* once paid this compliment to snow surveying: "In the Himalaya, Englishmen climb mountains for sport, but in America for business." As with the English, sport came first in America and, though a new science has arisen, the sense of pleasure and beauty that gave it birth will ever remain to foster it.

CELESTIAL MECHANICS IN THE SIXTEENTH CENTURY

By Dr. W. BURKE-GAFFNEY

PROFESSOR OF ASTRONOMY, JESUIT SEMINARY, TORONTO

IN the thirteenth century Saint Thomas Aquinas voiced the opinion: "Although the suppositions of the astronomers seem to explain the observed phenomena, we must not say that they are true; for perhaps the apparent movement of the stars may be explained by some other method not yet understood by men."[1]

Early in the sixteenth century Nicholas Copernicus was convinced that the suppositions of astronomers were false, and excogitated an alternative explanation. He attributed three motions to the earth. It rotated on its polar axis, completing a rotation in twenty-four hours; it journeyed round the sun in a year, with its polar axis inclined to the plane of its orbit; and it turned on an imaginary axis normal to the plane of its orbit, at the rate of one rotation each 25,816 years. The last-mentioned motion is the least spectacular, but the most original. Aristarchus of Samos had thought of the heliocentric possibility in 280 B.C.; Hicetas of Syracuse had favored rotation on the polar axis about 450 B.C.[2]

Nowadays there is a common misapprehension that the teaching of Copernicus gave rise to the question: "Does the sun move round the earth, or the earth move round the sun?" This is not precise. The antithesis of the question is not perfect. The question as to the cause of night and day was this: "Is it the sun circling the earth, or the earth *rotating on its axis?*" Scripture seemed to say the former; Copernicus held the latter.

Copernicus did not consider he was contradicting Holy Writ. Already, in the year 1377, Bishop Nicholas Oresme of Lisieux, whilst canon of Rouen, had shown how the Scripture might be read without deducing that the sun moves.[3] Copernicus was also a canon, and a pre-Reformation canon. He worked out his system about 1506 or 1507—before the Reformation was launched and religious bitterness stirred up. He had no axe to grind. He had not to fend for his living, as Kepler; he was not seeking fame, as Galileo; he was not a highly paid servant of a religiously intolerant king, as Tycho Brahe. He was not wedded indissolubly to one philosophic system; he was a member of no religious order. In a sense he was an armchair philosopher, but a very acute one. He was born of that aristocracy across whose minds the shadows of the future never pass. He studied classics, mathematics, astronomy, medicine and jurisprudence at the universities of Cracow, Bologna, Padua and Ferrara, and took his doctorate in canon law. He practised medicine before taking up his canonry. Astronomy was his hobby. He pooh-poohed the idea of publishing. About the year 1529 he wrote a synopsis of his theory for some who asked him.[4] It was then a time when he might well be hesitant about publishing. In 1517 revolt had been proclaimed in Wittenberg; in 1520 Luther had been excommunicated. But Copernicus had nothing to fear from Rome.

[1] St. Thos. Aq. in Arist. Stag. De Coelo et Mundo lib. Comment., Lib. II, lect. XVII.

[2] "Greek Astronomy," Sir Thomas Heath (London, 1932), xxxvi, xlix and 108.

[3] Pierre Duhem, *Revue générale des Sciences,* November, 1909.

[4] "A History of Science, Technology and Philosophy in the 16th and 17th Centuries," A. Wolf (London, 1935), 13.

His bishop, Giese, had all along approved, admired and urged him to print. In 1533 Johann Albrecht Widmanstetter enthusiastically expounded the Copernican theory to Pope Clement VII. In 1536 Cardinal Schönberg pleaded with Copernicus to benefit science and letters by giving his treatise to the world. The peace-loving canon shrank from possibly provoking controversy. His opinions were already widely talked of and were not on all sides well received.

The Abbot Francis Maurolycus wrote a book "Cosmographia" in 1535. He tells us he completed it "on Thursday 21 October 1535, the day that the Emperor Charles V came to Messina on his return from the African campaign." He published it in 1540. In it he demonstrates, by the customary arguments, that the earth is round and in the center of the universe. Having answered the classical objections, he continues: "And it would not be necessary for astronomers to refute any other principles as regards the earth, if diversity of opinion and human fickleness had not so grown that it is doubted whether one may perhaps believe and say the earth turns on its axis whilst the heavens stay at rest." He deals summarily with this new notion, without mentioning the names of any who hold it.[5] Nor did Luther mention any name when he spoke out his mind on the "new astronomer." "The idiot is bent on upsetting the whole science of astronomy," he said, and denying the Scriptures, for "Joshua bade the *sun* to stand still, and *not the earth.*" This was, according to Luther, June 4, 1539.[6] The following month George Joachim Rheticus, professor of mathematics in the University of Wittenberg, came to Copernicus at Frauenberg for first-hand information.

The canon and the heretic became fast friends. Copernicus let Rheticus write letters descriptive of his system—letters to be published, which they were, at Danzig in 1540, and Basle in 1541. No storm of protest broke: it was to a private correspondent Melanchthon wrote that the authorities should restrain such license of mind.[7] Satisfied with the reception which the *Narratio prima* of Rheticus received, Copernicus handed over his complete treatise for publication. Rheticus was to supervise its printing at Nürnberg. He did, until he was appointed professor at Leipzig in 1542. He then confided the task to Andreas Osiander, a well-known theologian at the university. Kepler, in his "Apologia Tychonis" (written in 1600–1601; first published in 1858), testifies he saw letters which passed between Copernicus and Osiander, in which the former protested that he wished it to be clearly understood that he held the solar system to be in fact as he described it; his theory was not an empty formula.[8]

The first copy of Copernicus' "De revolutionibus orbium coelestium" was delivered at Frauenberg a few hours before its author died, after months of illness, on May 24, 1543. Osiander had inserted a preface, supposed to be by Copernicus, protesting that the system was being put forward merely as a useful hypothesis. Bishop Giese wrote indignantly to Rheticus and to the senate of Nürnberg. But the damage was done. It was generally accepted that Copernicus was the author of the preface. Nothing approaching a public denial was made until Kepler proclaimed the truth in his "Astronomia Nova" in 1609.[9] Kepler had learned of the fraud from a colleague at Nürnberg. His announcement of it was not very public, for his

[5] "Joannis Kepleri Astronomi Opera Omnia," Dr. Ch. Frisch, editor. 8 vols. (Frankfort, 1858–1871), VIII, 584.

[6] "Luther," Hartmann Grisar, tr. E. M. Lamond, 6 vols. (St. Louis, 1915–1917), VI, 25.

[7] "History of the Planetary Systems from Thales to Kepler," J. L. E. Dreyer. (Cambridge, 1906), 353.

[8] "Kepleri opera omnia," I, 245.

[9] *Ibid.*, III, 136.

"Astronomia Nova" was printed privately, and not every one who wished to have a copy got one. Nor was it so generous a *geste* as at first sight might appear; for in that same book, on the back of the title-page of which he announced that Copernicus did not hold his theory as a mere hypothesis, he also demonstrated that, if the planets and the earth did move, they did not move in circles, as Copernicus had taught, but in ellipses.

After the appearance of Copernicus' book Melanchthon came into the open and declared (in 1549) it was a sin and a scandal to publish such nonsense.[10] Needless to say, in that God-fearing age there was no great rush to gainsay the pious and learned divine. Besides, to most men the new theory was not sense. The sun not going round the earth! Whoever heard of such a thing! It was patently opposed to the evidence of the eyes. And for the scientists Melanchthon had arguments drawn from the physics of the time to show that what he stigmatized as nonsense was in fact nothing else.[11]

With the sole purpose of defending the principles of Copernicus not a book was written until the year 1584; and not a single astronomer printed an unequivocal and complete profession of faith in them until Kepler did in 1596. Dreyer searched history, and all he could find prior to 1584 were the non-committal *obiter dicta* of two Englishmen and Pierre Ramée's destructive criticism of Ptolemy.[12] Robert Recorde in his "Pathway to Knowledge" (1551) wrote: "Copernicus, a man of great learning, of much experience and of wonderful diligence in observation, hath renewed the opinion of Aristarchus Samius, and affirmeth that the earth not only moveth circularly about his own centre, but also may be, yea, and is, continually out of the precise centre 38 hundreth thousand miles; but because the understanding of that controversy dependeth of profounder knowledge than in this introduction may be uttered conveniently, I will let it pass till some other time." Thomas Digges in his preface to "Alae seu scalae mathematicae" (1573) used the expression of Copernicus that the Ptolemaic system is like a set of heads and limbs taken off different people, which shows that it is not true. He studiously avoided saying that Copernicus had found the truth. (Much later, in 1592, he favored Copernicanism; but this is not to the point at the moment.) Pierre Ramée, in his "Scholarum mathematicorum libri XXXI" (Basle, 1569), was for overthrowing all existing systems, including that of Copernicus, and starting *de novo*.

In 1584 Father Diego de Zuniga, an Augustinian monk and doctor of divinity, of the University of Toledo, took up the cudgels on behalf of Copernicus. In a commentary on Job, published at Salamanca, he endeavored to show that the movement of the earth was in accordance with the words of Scripture. At the time he wrote, the Copernican theory was a matter of purely academic interest. Thirty-two years later, when it was a burning question, his book was relegated to the "Index."[13] That is another story.

Judging from published works, it would seem that the theory of Copernicus was less accepted in the last fifty-seven years of the sixteenth century than was the special relativity theory of Einstein in the second seven years of the twentieth century. Copernicus's "De revolutionibus" was reprinted only once during the century, at Basle in 1566, by the faithful Rheticus. On the other

[10] "Tamen asseverare palam absurdas sententias non est honestum et nocet exemplo."

[11] "Nikolaus Copernicus," Adolf Müller. (Freiburg, 1898), 85.

[12] "Planetary Systems," 346–347; 358–359.

[13] Dreyer, "Planetary Systems," 353.

hand, the "Cosmographia" of Maurolycus was printed four times between 1540 and 1570. And a similar work by Peter Apian, professor at Ingolstadt, ran to three editions comprising fifteen printings between 1524 and 1598.[14] In 1542 Erasmus Reinhold, professor at Wittenberg, published his "Theoricae novae planetarum," which he announced as "an introduction and inducement to the study of Ptolemy." It was reprinted in 1555, 1580 and 1601. In 1549 Reinhold put out a Greek and Latin version of the first book of Ptolemy; and in 1550 an edition of Sacro Bosco's "Sphaera," with a preface by Melanchthon. In 1551 appeared his famous "Tabulae Prutenicae," in the text of which he frequently refers to Copernicus, and calls him "another Atlas or Ptolemy." But, he tells us, the tables were constructed from the observations of Copernicus, Ptolemy and Hipparchus, and, besides his observations, he borrowed nothing from Copernicus except outlines of his explanations (*demonstrationum vestigia*).[15] The "Prutenic Tables" superseded all previous astronomical tables. They were used by every astronomer in the last half of the sixteenth century; they were used by John Field in preparing his "Ephemeris for 1557"; they were used by Father Christopher Clavius, S.J., in the making of his calculations for the Pontifical Commission (1576–1582) for the reform of the calendar. Father Clavius had, in 1570, published a commentary on the "Sphaera" of Sacra Bosco (John Holywood), in which he noticed the theory of Copernicus and rejected it on scriptural and physical grounds. The "Commentarius" of Clavius proved most popular and ran to eleven impressions before the end of the century.[16] Professor Kaspar Peucer, of Wittenberg, in his "Hypotyposes orbium coelestium" (1571) says he passes over the hypothesis of Copernicus lest beginners be offended and disturbed thereby; and, further on, that the absurdity of Copernicus, so far from the truth, is offensive.[17] And Michael Maestlin in his "Epitome Astronomiae" (1582) expounded all the old theories without even mentioning Copernicus.

At the end of the sixteenth century the most eminent astronomer living was Tycho Brahe. When he died, in 1601, Kepler was but a budding sprout; and Galileo had not yet built a telescope. Brahe's work was overshadowed by the discovery of the telescope; but his name is writ in history as the most accurate naked-eye observer of the heavens since the days of Hipparchus (B.C. 140). Brahe jumped to fame through his tireless watching of the Nova of 1572—the variable B. Cassiopeiae.[18] He published an account of his observations under the title "De nova stella" (Copenhagen, 1573). The tract was widely read; its author was in demand throughout Europe for public lectures. One of these, delivered in 1574, was published for the first time in 1610. In it he acknowledged that Copernicus had been justly called a second Ptolemy, who by new hypothesis, deduced by the admirable skill of his genius, showed a more accurate knowledge of the motions of the stars than all who had gone before him. And though, he said, the Copernican theory was somewhat contrary to physical principles, it admitted nothing contrary to mathematical axioms, as did the hypothesis of Ptolemy.[19] Brahe's words bear a striking resemblance to words in the "Quaestiones novae" (Basle, 1573) of that Wursteisen whom Galileo records

[14] "Kepleri opera omnia," VIII, 584, 586.

[15] *Ibid.*, VIII, 587–589.

[16] "Bibliothèque de la Compagnie de Jésus," Carolus Sommervogel, 10 vols. (Paris, 1890–1909), II, Col. 1212.

[17] "Kepleri opera omnia," VIII, 565.

[18] "Katalog und Ephemeriden Veranderlicher Sterne fur 1935," R. Prager (Berlin, 1934), 29.

[19] "Tycho Brahe," J. L. E. Dreyer (Edinburgh, 1890), 74.

as having given lectures on Copernicanism in Italy. In the year 1575 Brahe was considering leaving his country for good to take up work at Basle, when he received a munificent offer from his king, Ferdinand II of Denmark. He accepted. He was presented with the island of Hveen, a magnificent observatory and a life pension. His opinions were fettered. His patron was a stout Lutheran; he had already dispensed with a professor whose orthodoxy had been called in question. But Brahe had plenty of reasons for rejecting the theory of Copernicus. First of all, it was contrary to the teaching of Scripture; secondly, if it were true there should be an annual parallax of the stars—and he, with the best instruments ever made, could detect none—and thirdly an objection of Clavius was unanswerable—a stone dropped from a high tower should land far from the foot of the tower. Brahe was professedly a Ptolemaist until he printed, privately, "De mundi aetherei recentioribus phaenomenis" in 1588. In this he proposed a new system, known to this day as the Tychonic system. It supposed the planets to circle round the sun which traveled round the stationary earth. He declared that he thought of it four years before "as if by inspiration."[20] Another man had been inspired with the same idea eighteen hundred years before—either Apollonius of Perga or another.[21] And one Reymers, also known as Ursus, put out a book, the very same year as Brahe printed privately, expounding a similar theory. Brahe accused him of pirating; but Dreyer, the devoted fellow-countryman and biographer of Brahe, admits that there is not the least proof of plagiarism. The principle of the Tychonic system was so obvious a *via media* between the Ptolemaic and Copernican systems that it would naturally occur to several people. In fact, there was also a Scot, Duncan Liddel, who also claimed to have found it. But why this epidemic of getting away from Ptolemy? Tycho wrote that he was induced to give him up as the result of observations made in 1582–1583 which showed Mars, at opposition, nearer the earth than the sun. Now, Tycho's manuscripts passed to Kepler, and Kepler found that the observations showed nothing of the kind. And, furthermore, in a letter written in 1584 Tycho said plainly that these observations showed Mars to be further away and Copernicus to be wrong! Dreyer admits himself nonplussed by the contradiction.

Tycho and others were straining at the leash of Ptolemy. Why? Is the answer to be found in history extraneous to the history of astronomy? From 1576 to 1591 there was running wild through Europe a philosopher of unbridled brains, who shook the thoughts of the times whilst scattering the seed of modern philosophic doubt—Giordano Bruno. Bruno was born at Nola, near Naples, of poor parents, in 1548. As a boy he aspired to enter a religious order. His extraordinary intellect compensated for his lack of wealth. At the age of seventeen he donned the habit of St. Dominic. The young religious was noted for his lively imagination and his restless spirit. He read indiscriminately; he formed a profound aversion for Aristotle and Scholasticism. In spite of this he was ordained priest and exercised the priestly office in various places. From scepticism he passed to open heresy. It was related at Rome that he cast doubt upon the possibility of a Holy Trinity and the divinity of Christ. He was called there to clear himself. He proved recalcitrant and was threatened with trial by the Inquisition. He sought safety by flight, 1576. He settled in Geneva, where, to gain admittance to the university, he professed his faith in Calvinism. In 1579 he was jailed for

[20] Dreyer, "Planetary Systems," 356.
[21] Heath, "Greek Astronomy," lv.

defamatory libel against a professor of the university. Upon his release he shook the dust of Geneva off his feet, and became a sworn enemy of Calvinists.[23] At Toulouse he obtained a chair of philosophy, assailed Aristotle for two years, and added to his munitions by studying the new astronomy. He then moved to Paris, devoured the "Ars generalis" of Lully, and became an authority on mnemonics. He obtained a special professorship, in philosophy, and wrote on philosophy. He also wrote, at this time, his comedy "Il Candelaio," which rates among the most obscene plays ever written.[24]

In 1583, when France was in a turmoil, Bruno crossed to England, where priests were hanged. During his sojourn he flattered the Virgin Queen, and wrote. Amongst other books, he wrote "La Cena delle Ceneri," the popular attack upon the Ptolemaic system; it was published in Paris in 1584, the year in which Tycho Brahe got his "inspiration"; and the year in which the French historian Jacques Bongars visited Brahe at Uraniburg.[25] Bruno had been refused permission to lecture at Oxford. In his "La Cena" he turned aside from his main purpose to express himself on that university; it was "a constellation of the ignorant, pedantic and obstinate; and a mixture of donkey and swine." In 1585 he was back in Paris, and sought reconciliation with the Catholic Church; he refused to pay the price—return to his order. He left France for Germany, and passed from city to city. At Helmstadt he was denounced by the Lutheran superintendent as an "assassin of souls." At Wittenberg he did well, praising Luther; but the tide turned, and in 1588 the Calvinists drove him out. At Frankfort, in 1591, he received an invitation to Venice. One Giovanni Mocenigo wished to learn the mnemonic art and how to read thoughts. The following year his pupil-host handed him over to the Venetian Inquisition. An attempt has been made to explain this inhospitable act by linking the facts that his host had a handsome wife and that the charge laid against him was not only heresy but also that "he had taken great pleasure in women." However this may be, the Roman Inquisition demanded, and obtained, his extradition, on the grounds that he had long been "wanted" there, as an apostate priest and a fugitive monk.. He was held for eight years and given every opportunity to recant, before being burned, as a traitor to his faith, February 17, 1600. "The fate of Giordano Bruno," says Dreyer, "can hardly have been influenced by his advocacy of the earth's motion, for he had to set forth a sufficient number of startling ideas to provide stakes for many scores of heretics."[26] And the best that A. V. Butler can say of him is that: "as an apostate monk, a loose liver, the wielder of an acrid pen, he had at least given provocation, and caused something of a scandal in several countries of Europe."[27] He was, of course, no astronomer.

Whilst Bruno was at Wittenberg there came to sit at Michael Maestlin's feet, at Tübingen, a poor scholar of scarcely seventeen summers—Johann Kepler. Michael Maestlin's "Epitome Astronomiae" was reprinted that same year, 1588. As has been said, it was thoroughly Ptolemaic, with not a word to say for Copernicus. But Kepler tells us that Maestlin taught Copernicanism. It would seem to have been the fashion of the time to say what one thought, but to write what one ought. Maestlin's teaching Copernicus was a happy fault.

23 Pastor, "The History of the Popes," XXIV, 204.

24 Pastor, XXIV, 205.

25 Dreyer, "Tycho Brahe," 157.

26 "Planetary Systems," 416.

27 "The End of the Italian Renaissance," *The Cambridge Modern History*, III, 466.

His pupil was convinced of the truth of the Copernican system. When elected to the position of provincial mathematician at Grätz (1594), he took it for granted, and gave much thought to the questions: Why did the all-wise Creator place the planets as he did? Why were the dimensions of the orbits what they were?[28] Finally he found what he believed to be the true solution; and he carefully noted the date of his discovery —a date which he expected would go down in history, 9/19 July, 1595. He wished to rush into print; he wanted to tell the world that in designing the universe the Almighty had used the number, and relations between the dimensions, of the five regular solids—the cube, tetrahedron, dodecahedron, icosahedron and octahedron, and that his, Kepler's, discovery was consistent with Copernicus's theory. But he also wished to publish under the egis of the University of Tübingen, and this was not so easy; the Copernican theory was not in good odor among the theologians there.[29] At length, however, his "Prodromus" was off the press (December, 1596); it has claim to be the first and only publication of an astronomer in the sixteenth century to unequivocally defend the Copernican system. As fates would have it, it was this same Kepler who was (thirteen years later) to prove that the Copernican theory was false, that the earth and planets did not move in circles round the sun, but in ellipses.

If Kepler's "Prodromus" did nothing else, it served to introduce him to the notice of the scientists of the time. It led to his holding correspondence with Tycho Brahe; and after Brahe had become imperial mathematician to the Catholic Emperor Matthias, at Prague, Kepler joined him (in 1600) as assistant. In 1601 Brahe died; Kepler succeeded him as imperial mathematician and received his manuscripts. If, in after years, he renovated the whole science of celestial mechanics, it was in large measure due, as he acknowledged, to the thirty tireless years of work of Brahe. Without Brahe's observations Kepler could never have achieved what he did. Brahe must not be forgotten. "Si fiers que nous puissons être des succès d'aujour'hui, nous ne devons pas oublier ceux qui, par leur travail opiniâtre et leur intuition géniale, ont ouvert les voies sur lesquelles nous continuons à avancer."[30]

28 "Kepleri opera omnia," I, 106–109.
29 *Ibid.*, I, 19–24.

30 Louis de Broglie, *la Revue d'Optique théorique et instrumentale*, 79, 1927.

AN ADVENTURE IN ETYMOLOGY

ORIGIN AND MEANING OF SOME ANIMAL NAMES

By ERNEST INGERSOLL
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The first-comers from Europe to this part of the world were eager to get not only a knowledge of its extent, climate and geographic features, but also of its productions. French and Basque fishermen before the time of Columbus knew of the cod-fishery in the waters about "New-Found-Land," and were vaguely acquainted with the natives of its shores and with certain fur-bearing animals. Later, French navigators explored the valley of the St. Lawrence with an eye to extending their king's dominion and wealth and the influence of the Catholic church, but paid only careless attention to the plants and animals they encountered. Much the same imperial notions and objects actuated the Spanish conquerors, who, in the sixteenth century, penetrated the region north of Mexico. Their reports contained small mention of natural products, for their efforts were spent on hunting for mines of gold or gems or on the Christianizing of whatever human inhabitants were discovered.

From the records of these primitive French and Spanish expeditions we shall gain therefore little help in our search for the origin and significance of the vernacular or "common" names of North American mammals—to which this essay is devoted. Our debt, on the contrary, is with few exceptions owing to the English-speaking adventurers who later obtained possession of the vast space between St. Lawrence Bay and the Gulf of Mexico. They were intent primarily on neither gold nor religious missions, but on trade and self-sustaining colonies. These explorers, planters and traders—never crusaders—were wide awake to sources of wealth and eagerly examined every path to that end; hence their reports and letters to the rulers and people of the Old World abound in information as to navigable rivers, useful forests, tillable land and the like, and frequently included observations and lists of trees, animals, fruits, etc. Each "home"-going ship carried samples of almost everything noticed that was transportable.

In this way, from the very beginning of occupation along the Atlantic coast, specimens of many American mammals, birds and other creatures fell into the hands of European naturalists of that time (including Linnaeus), each specimen "marked for identification" as fairly as the sender knew how. It must be remembered, however, that these early residents on our shore—whatever their virtues otherwise—were ignorant not only of zoology, but most of them were townsmen lacking an English farmer's scanty knowledge of such things. When they saw a bird or flower that somehow suggested what they had happened to have known in the "old country" they flung that name upon it—and made some dreadful mistakes! Therefore the descriptions as to haunts and habits attached to their specimens were likely to be indefinite, and the exact source of each was rarely indicated; at the same time the European classifier had equally hazy notions of American geography. Thus honest ignorance erected a difficulty in the way of the word-tracker who

is struggling with what Dr. Elliott Coues once called "ornithologicalities."

Having disposed of these facts and reflections I will now turn to the anticipated topic of this paper, namely, an examination of the why and wherefore of the English-American names of our more or less familiar mammals. Any zoological group asked to account for its names will yield interesting paths to be traced, and a fair trial of the sport may be made with the comparatively short list of North American mammals, which we may conveniently investigate alphabetically. The first name to respond will be *Antelope,* meaning the pronghorn.

Here our feet strike a stumbling-block at the very start, for, in addition to the fact that our pronghorn is not in that class of old-world ruminants, but only looks like it, we soon learn that "antelope" is an antique Greek noun that has worried etymologists from 'way back. It seems to have been a synonym of "gazelle" and shared with that term the sense of bright-eyed—a feature poets have always celebrated. In proper classification our pronghorn (a model of suitability in names!) stands by itself as an erratic cousin of the goats; and the early Spanish explorers called it simply a little goat, which accounts for the name cabrée or cabrit (Spanish *cabrito,* a kid) still heard along the Mexican border.

At the head of the words indexed under B is the *Badger.* No fur-bearing animal in the world, perhaps, is more widely known than this—at least by name. This matter of its label is a curious one, especially as the shaggy little beast has two names, an older and a newer one; in fact, the American species, differing from the historical European one mainly in coloring, is alone entitled to the latter. Since English speech became organized the British have called this animal "broc," apparently a Welsh word carrying the idea of grizzle or grayness, suggested by the color of its coat. This term still holds good among country people, but long ago British sportsmen translated it and spoke of the animal simply as "the gray." In fact, the book-name badger was not introduced into English speech until the sixteenth century, and most dictionaries still instruct us that it means nothing more than "wearer of a badge," referring to the white stripe down the creature's face; and they try to support this explanation by quoting another almost forgotten designation, "bauson," meaning piebald.

Opposed to this, Dr. W. W. Skeat and his school of etymologists declare that the name badger came into Britain (and thence over here) by way of Italy and France, supporting their view by showing such changes in letters, pronunciation and so forth as obscure the history of hundreds of our words of foreign birth. The French called wheat *ble,* which represents the core of the Latin *ablatum,* the ancient term for "corn" (cereals), particularly wheat. Roman grain-merchants seem to have been so distrusted by their customers that they were dubbed "corn-stealers," and so were classed with the badgers that damaged Italian farmers' crops and were hated as pests. The Italian epithet for both the mischievous little beast and the cheating corn-dealer passed into old French as *bladier* and soon crossed the English channel. A more or less rude Britisher of former times, as now, would pronounce it "bladger," and the over-easy dropping of the letter *l* left it sounding as badger. Really this reasoning is fairly straight. By a precisely analogous loss of an *l* our speech has acquired the animal-name *Bat* from the *Icelandic* Blatta, a flutterer; Germans call bats flittermice. In modern French, badger is *blaireau*—a word used to-day in Quebec, usually sounding, however, more like "braro."

Queer evidence that we have derived the English word badger and the stigma involved with it from Roman grain-market talk is found in the writings of John Strype, an English historian of the early eighteenth century, who recorded much about London and its bridges. Famous old London Bridge, begun in the twelfth century and lasting 400 years, had a score of arches to sustain its roadway and picturesque burden of houses and temples. Strype says that in Queen Elizabeth's time much complaint was heard in London over the extortionate prices asked by both millers and dealers for flour and meal. To check this oppressive condition the magistrates set up in several of the arches of the bridge water-mills for public benefit. "The profit of these mills was that whereas in time of dearth the common people could not have their corn ground under four, five or six pence the bushel, and many times could not have it ground at all in a short space, by means whereof the people were constrained to buy meal in the market at such prices as the seller himself would demand, this would be remedied by these mills. Also the badgers, or meal-sellers, advanced prices as they listed." Here history shows the former food-merchants and millers in the same bad light as their Italian predecessors, and having the same spiteful nicknames—Badger! Cornstealer!—shouted at them on the banks of the Thames as used to be hurled at them in market-places beside the Tiber; and in reality the market-men seem to have deserved their bad reputation far more than the animal did his.

Bear and *Beaver* are what etymologists call Old High German words, so old that why they took that shape or what were the animating ideas that led to it are quite beyond call. Most of the different bears are so simply named by color or place that no explanation is required, but a word may be pertinent about our "grizzly." This master of the western mountains was brought to scientific notice by the Lewis and Clark expedition in 1804. Captain Lewis gave it the name "grizzly," which means having a grizzled coat; but he also wrote "grisly," which (if intentional) implied the high respect he had for its power and prowess. Doubtless this "grisly" view led Ord to give the dreaded animal the Latin specific label *horribilis*—horror inspiring—rather than the hoary hue of its coat (as if "frosted" with white hair-tips), since it was soon learned that its prevailing color is some shade of brown, as in all other northern bears except the polar species. Indeed it seems to be agreed that the root-notion behind the modern word "bear," in its various forms between India and Iceland, was a prehistoric expression of the creature's characteristic appearance—it was the "Brown One." A substantial reason for believing this explanation is the common way of speaking of a bear as bruin, which is simply the Dutch adjective "brown." The nickname "Old Ephraim" given to this bear by western hunters was doubtless in reference to the character of warrior belonging to that fighting son of Joseph and the tribe he founded in Judah's Canaanitish wars; but why the frontiersmen styled him "Moccasin Joe" is unexplained, unless it was suggested by its footprints.

Beavers, like the bears, owe their very ancient name to brownness.

Bison comes next in order. This has been the label, under various spellings, as "bisonte" and "wesant," etc., of the wild forest beast the Romans called "aurochs," learned from the Germans, and which we popularly but erroneously know as the *Buffalo.* Spanish explorers of our Southwest found it in northern Mexico and adopted the Indian name

"cibola," soon forgotten. French adventurers who met the animal in southern Ontario spoke and wrote of it merely as a native sort of beef-cattle (*le boeuf*); the first English colonists learned of its existence under this name, modified the French word into "buffle," and this soon became altered into buffalo. It is unfortunate, as has been said, that most of our more conspicuous mammals and birds were first seen and reported by persons ignorant of zoology and reckless of diction.

A good example of such misnaming is suggested by the word *Cony,* nearly obsolete on this side of the Atlantic. It designates in Britain the common small burrowing leporid to which alone the name properly belongs. Newcomers into New England saw our little cottontail and dubbed it "cony" (as later men did the pika), not observing that it did not burrow and was really a small hare; and so we call all our hares rabbits. Another misnomer is the book-name *Civet-cat,* although it is neither one nor the other, but is in reality a distant cousin of the raccoon properly named "cacomistl" (Mexican Indian). Fortunately the people of Arizona, who find it an agreeable pet, have suitably named it "ringtail." This is a neat and pretty creature built like a 'coon but looking more like a fox; so the first scientific describer hunted up a Greek word for fox and added "bassarisk" to his index.

Coyote, our red, prairie or "barking" wolf, brought with it from Mexico its Anahuac (Indian) name coyotl; this in American speech soon lost its terminal *l* and acquired an *e,* which made the proper pronunciation coy-yó-te, not ký-yote, as most plainsmen perversely sound it.

Four other mammal names have the initial C—caribou, carcajou, chicaree and chipmunk. *Caribou* must be credited to Canadian French, and probably was taken from some eastern Indian dialect, perhaps of Newfoundland. *Carcajou,* the wolverine, but often mistakenly applied to the lynx or the puma, is another French-Canadian borrowing, as we shall see when we come to "wolverine." *Chicaree* is a nickname for the red squirrel used by Audubon and other early writers, suggested doubtless by the querulous chatter of this excitable little rodent. Imitative, too, are *Chipmunk* and the forgotten "hackee" for the striped spermophiles now often, in the Northwest, confused with other species as "gophers." *Cougar,* a name of Brazilian origin, is still prevalent in the southern United States for our big forest cat or "mountain lion," which will be further considered when we come to *Puma.*

Deer is a term little changed from remote times in the north of Europe, signifying wild—a wild thing. Originally it seems to have covered any wild animal, and this broad sense has lasted, at least in English, until comparatively recent times—witness Shakespeare's, in the familiar line in "King Lear," act 3, "But rats and mice and such small deer."

When or how the word came to be restricted to the family of woodland ruminants we call deer is obscure. My impression is that the change is associated with the rise of the oppressive game-laws enforced by the kings and feudal lords of England in the twelfth and thirteenth centuries, as indicated in history and in such traditions as the ballad of Robin Hood. Under such royal influence and laws the red deer and the roe became the only "game" sportsmen considered worth while, and popular opinion and language gradually followed. I may here quote in part remarks by the learned author of Bell's "British Quadrupeds," who wrote:

The derivation of the English names applied to the deer tribe is interesting, showing how completely the simple Saxon words of the stout yeomen and outlaws ousted the Norman-French terms used by princes and barons. Thus deer is the Anglo-Saxon *deor,* its primary meaning signifying simply a beast (German *thier,* Greek *ther,* Latin *ferus*). Stag originally meant a male animal of any species, as in the Icelandic *steggr,* a male, and the Scotch *staig,* a young horse. *Heort* (hart) and *hind* are also Saxon. The fallow deer takes its name from its color (Anglo-Saxon *fealo,* yellow). "Buck" is probably from the Teutonic *bocken,* to strike—an animal which butts with its head; hence it has become the general name of the male beasts of the chase, even including those which have no horns, as the hare and rabbit. "Doe" seems to contain the sense of tameness, harmlessness, and "fawn" is thought derived from an old French word for offspring; but more modern students refer it to an Icelandic source.

The common forest deer of the eastern states has been styled Virginian from the beginning, but when found in the West it was naturally christened white-tail, from the conspicuous snowy "feather" it elevated when startled, or willow deer from its wise habit of sticking to the shelter of the willow-bordered watercourses in the open regions there. In contrast, the larger plains deer is known locally as blacktail, mule or jumping deer, in reference to characteristic features and gait. Two other American species of this family call for more special notice—the wapiti and the moose.

Moose is one of the few names of American animals accepted from the Indians, and is a near reproduction of what the Algonkin-speaking tribes called this big, flat-horned deer, and came into use as early as 1632. The first Frenchman who attempted to settle about the Bay of Fundy mentioned in their records the first deer they saw by queer provincial names, but as to the moose, a creature utterly new to their eyes, they could do no better than to call it simply *l'original,* showing that they failed to recognize it as the counterpart of the great elk of Scandinavia, of which very likely they had no knowledge. Early British colonists, however, recognized the resemblance. In his "New English Canaan" (London, 1632) Thomas Morton, listing the animals of New England, says: "There are in this country three kinds of Deares. . . . First, I will speake of the Elke, which the Salvages call a Mose; it is a very large Deare, with a very faire head & a broade palme, like the palme of a fallow Deares horne, but much bigger."

The Virginians fell into great confusion between these two deers, a confusion of which we are not yet quite rid, for when on the James River they first saw or heard of a "great" stag they assumed that it was the elk of northern Europe, when in truth it was our wapiti. I had made considerable search to ascertain where and how that mistake first happened when I discovered that Ernest Seton had answered my question in his magnificent book "Northern Mammals." Seton had found that in 1605 Captain George Weymouth recorded in his "Voyage to Virginia" "that the savages sign unto us a certain deer with horns and broad ears which we take to be Olkes." As Seton tells his readers—

This is the earliest known use of the word "olkes" or "elk" with reference to the American. It appears in the latter form in 1650, when Virginia is credited not only with abundance of deer, but also with "elks bigger than oxen." [This information Seton derived from the Force Tracts, Vol. 3, No. 11.] . . . After this date the number of travellers increased in America, and their accounts frequently included descriptions of "the great stag that was of the bigness of a horse."

Seton then gives two interesting quotations from two of these early writers, as follows:

Thus Mark Catesby, in 1731, remarks on "the stag of America . . . they usually accompany the Buffaloes, with whom they range in droves

in the upper and remote parts of Carolina, where, as well as in our other colonies, they are improperly called Elks. The French in America call this beast the Canada Stag. In New England it is known by the name of the Gray Moose to distinguish it from the preceding beast, which they call the Black Moose. . . .

In March, 1806, Dr. B. S. Barton published "An Account of the Cervus Wapiti or Southern Elk of North America." He remarks: "As the Elk has not to my knowledge been described by any systematic writer on Zoology, I have assumed the liberty of giving it a specific name. I have called it Wapiti, which is the name by which it is known among the Shawnees or Shawnese Indians. . . . This animal is generally known in Pennsylvania and in other parts of the United States by the name of Elk."

Mr. Seton assures us that this is the first use in print of the word "wapiti," so far as he knew, and probably he is right.

Resuming our progress, the next item is *Gopher*. This is our spelling of the French word *gaufre* (honeycomb), which was used by the French pioneers in Louisiana to indicate a creature that made clustered burrows in the ground, fancifully likened to the cells in a honeycomb. It was also applied (badly) to the large southern tortoise and burrowing kind of snake; but the present familiar use of the term did not begin until about 1850, when Kennicott reported that the "pouched rat" was known as "gray gopher" among Illinois farmers. Since then almost any ground-squirrel is a "gopher" in the West.

Groundhog is the senseless name, originating apparently in the southern states, for *Woodchuck;* it persists through the silly newspaper preservation of a still more senseless weather-proverb, imported by German immigrants in Pennsylvania.

Under the initial H come such remotely antique generic words as hare, horse, hog and the like. *Hare* has descended from the Sanscrit verb "to jump." *Hog* may be guessed at; my guess is that it is simply an imitation of the animal's grunt. *Horse* contains no suggestion of any equine voice. The horse seems to have been distinguished among the beasts in the primitive German forest as "the running one"; but whether this apt recognition-mark in words originated with the first Eastern immigrants, and hence belongs wholly to the European forest pony, is not clear.

Jaguar, the big spotted cat of tropical America, a century ago common in eastern Texas and the swamps of Louisiana, preserves in English its name among the Guarani Indians of Brazil, literally signifying "big dog." Although so leopard-like, it is called "the tiger," except in Mexico, where it is known as the *ocelotl* of the woods.

Next comes *Lynx.* As we spell it the word is pure Latin, behind which is a long ancestry carrying the idea of light (Latin *lux*). The application in this case appears to be in the sense of brightness, for this animal seems to have been regarded by the ancients as "the cat with the shining eyes." All cats' eyes glow by reflected light under favorable conditions, and the eyes of the large species shine more than others. Hence the big fierce lynx has become especially noticeable in this respect. Also in another way. All cats see well in gloom and have been popularly credited with ability to sparkle in total darkness, which of course is impossible. On the principle that a big cat has more power than a small one the belief grew in the old fable-loving times that the lynx could look through opaque objects. Hence the original credit became extended from shining eyes to all-seeing ones, and we speak of any animal or man as "lynx-eyed" because ancient fabulists said so. The old Canadian French hunters knew this wildcat as *loup cervier* (deer-wolf), commonly pronounced "lucivée."

Mammoth and *Mastodon* are scientific

terms not generally well understood. The extinct elephants named mammoths are not so called with reference to enormous size, but from a Yakut word (in Russian *mammot*) meaning a burrower, because when the first specimens were discovered entombed in the frozen cliffs of Arctic Siberia, the Yakuts reasoned that when alive they had lived underground—in fact, were huge moles! In truth, the mastodon owes its scientific name to a peculiarity in its dentition.

Mole seems to be a shortened form of the Middle English "mould-warp," meaning an animal that throws up the mould or soil. Scotsmen still speak of the mole as "modewarp," as frequently occurs in the poems of Burns and other writers.

Moose is one of the few animal names we have adopted from the Indians and closely follows in pronunciation the Algonkin (Abenaki) original, the meaning of which is "wood-eater."

The name *Muskox* is a misnomer in a double sense as applied to this Arctic relic of the Pleistocene. It is not at all an ox, but stands by itself between the cattle and the sheep, as indicated by its generic label *Ovibos;* furthermore, it is not at all musky. Stefansson had much experience with it in the Western Arctic islands, and agrees perfectly with Sverdrup and other competent observers that no taint of musk belongs to this fine animal either when alive or as edible flesh. Stefansson recommends dropping this deceptive name, and calling these animals *Polar Cattle.*

The *Muskrat,* on the contrary, has a good and suitable name, for it is both a rat—a sort of huge meadow-mouse—and its pelt, at least, is unpleasantly odorous; nevertheless the animal does not owe its name to these characteristics, but to the wide-spread designation of it in the Algonkian language, varying dialectally in the various tribes. Captain John Smith reported it in 1616 as "musquassus" in the Powhatan speech of Virginian Indians; the Crees of the Northwest said "muskquessu," meaning "it is red"; Morton (1632) learned it from the Abnaki as "muskewashe"; and the early Canadian trappers pronounced it "musquash," which the Yankees borrowed and have never forgotten, but unhappily has been displaced by the unimaginative form "muskrat"!

Under the initial *O* are to be listed here three mammal names—ocelot, opossum and otter. *Ocelot* calls to mind that beautifully mottled cat of Texas and southward, whose name is a shortened form of the word *ocelotl,* which Mexican Indians are said to apply to wildcats generally, but specifically to *el tigre,* which we know by its Brazilian epithet as jaguar. Lesser cats are distinguished by descriptive adjectives. The ocelot, as we know it, is termed "field-jaguar" because it chooses to live in open hunting-grounds, while "tigre" is a beast of the heavy forests and the mountains.

Ask any group of persons to tell you the origin of the name *Opossum,* and the answer will probably be that it came from Australia, whereas the truth is quite otherwise. This queer little beast was an astonishing novelty to the colonists at Jamestown, Virginia, and its peculiarities were described at some length by Smith and Heriot as early as 1610. They spelled its Indian name *opassum.* When, many years later, the zoology of Australia came to be examined, animals of the same kind were found there, and the Virginian novelty and its native name were recalled; soon all the smaller Australian marsupials came to be known as opossums.

Pekán, our big northern marten, was adopted as a distinction very early from the Abnaki Indians by the Canadians and was first recorded in English in a translation of Charlevoix's "Travels"

about 1820. Few of our mammals have so many aliases. The first specimen of its skin sent to a naturalist in Europe unfortunately carried the label "fisher," and this clung to it in the books, although wrong, for this marten does not catch fish as a part of its habitual fare, although it readily steals and eats one when it finds it serving as bait in a trap—a common practice in Quebec. Hunters also speak of this able weasel as "black fox" or "black cat," which are excellent examples of the sportsman's usual carelessness in language. In most books it is indexed as Pennant's marten, because the first skins to reach Europe and become classified were sent from Canada by that exploring naturalist about 1775.

Pika, the timberline "cony" of the Rocky Mountains, inherits this Siberian name from a similar Alpine species so called in eastern Europe; but our pika is more commonly known as "little chief hare"—an amusing nickname given it by the Indians of northern Canada, and introduced to us by Richardson.

Porcupine, that is, "spiny pig," calls for no remark beyond the fact that it is substantially the same in all the Romance languages. Father De Smet, the famous missionary to the Indians of the upper Missouri region, says that his parishioners called it "prickly beaver." They explained that in old times porcupines and beavers were brothers and lived in company; but the beavers became so disgusted with the former's indolence and dislike of water that one night they left the sleeping camp to their lazy friends, and ever since the two have dwelt apart.

Porpoise is merely an old French word meaning "sea-pig," replaced in modern French by *marsuin,* which is a gallicized form of the German name *meerschwein,* sea-pig again. So the slow and bristling porcupine, carefully avoiding water, and the sleek and agile porpoise, which lives in it, are, etymologically, "sisters under the skin," to borrow Kipling's striking phrase.

This brings us to *Puma,* our own peculiar beast of prey. This is its native name in Peru, introduced to us, I think, by the Swiss naturalist and traveler Tschudi about 1840, and now generally adopted by zoologists. This fine, self-colored cat is remarkable as a species for its distribution from Maine and British Columbia to Patagonia, and also for its many names. It seems to have been first encountered in what is now the United States by the early settlers in New England, who considered it "panther," which, by the way, is an old Greek name for the leopard. Yankee hunters pronounced the word "painter," as is perpetuated in Fenimore Cooper's novels of frontier life; and they also called this greatly feared animal "catamount" and "carcajou"—the latter a mistake, for that is the French-Canadian name of the wolverine. In the southwestern states this cat is usually referred to as "cougar"; but everywhere else in the West it is "the mountain lion." In view of this confusing diversity it is a fortunate circumstance that the short, easy and well-born name *puma* has come into general use.

This somewhat discursive essay may end with a few notes under W, X, Y and Z. *Weasel* and *Wolf* have been current so long in our speech that nothing but guesses at their philological birth remains. Any one who looks at a *Weasel*—how slender and shriveled its body seems—must think of it as "wizened"—its origin? *Whistler* is merely a translation of *le siffleur,* naturally given to the Rocky Mountain cousin of our eastern woodchuck by the French fur-trappers of old times because of its whistling shout. The word *Woodchuck* has been derived from

the name of the animal among the northwestern Cree Indians and has no reference to the forest or anything meant by "chuck."

The name *Wolverine* has been subjected to much unsatisfactory inquiry. That brilliant scholar, Dr. Elliot Coues, devoted two pages in his closely studied treatise on the fur-bearing animals to this hated beast of the Canadian wilderness. The Cree Indians called it *quickhatch* and the French Canadian trappers *carcajóu,* why is unknown. To add to the confusion our patron saint Linnaeus, after examining his first skin, gave it the Latin specific name *luscus,* one-eyed, because the specimen happened to have lost an optic in the process of killing or skinning, just as he named the first bird of paradise he received, *apoda,* footless, not realizing that Malays cut the legs off the skins of these birds, destined to the feather-market, for convenience in packing. The result of Dr. Coues's investigation was the final sentence, "I have no idea what the meaning of the term may be."

Not liking to end this pleasant discourse on so dolorous a note, let me return for a brief moment to that beautiful group, the cervine deer. Surely, of all this family none is finer than our noble stag, the wapiti. It is most fortunate that this splendid deer has inherited from a purely native source a really distinctive designation, *Wapiti* (white-rumped), a name so good that it has been adopted not only by ourselves in place of the erroneous "elk," but also by naturalists and sportsmen abroad as an appropriate and convenient means of separating in a casual way the Asiatic forms of the species from those of Britain and eastern Europe.

SCIENCE, POPULATION AND SOCIETY[1]

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A LARGE number of theories purport to trace some relationship between population density and the rate of scientific and technologic advance. Most of these assert that there is a positive correlation between high population density and scientific progress.[2] Paul Jacoby has even attempted to reduce the relation to a formula. He maintains that since the frequency of geniuses and of their inventions is directly related to density of population and urbanization, one may formulate the expression of a law, $u = f(xy)$, in which density $= x$, urbanization ratio $= y$ and the frequency of genius $= u$.[3] According to Adolph Coste, one of the most extreme of these theorists, "the inevitable increase and the progressive concentration of populations . . . is the determining condition without which inventiveness could not be exercised."[4] Feldhaus, Cornejo and Vierendeel have expressed the same opinion.[5]

There are several obvious reservations to this theory. In the first place, as these theorists' own data frequently show, this correlation is far from perfect. In so far as the variable of population density has

1 The author gratefully acknowledges the financial assistance provided by the Harvard Committee on Research in the Social Sciences.

2 A survey of many of these theories is to be found in P. A. Sorokin, "Contemporary Sociological Theories," pp. 388–412. New York, 1928.

3 Paul Jacoby, "Études sur la Selection Chez l'Homme," pp. 542 *ff*. Paris, 1904.

4 Adolphe Coste, "Les Principes d'une Sociologie objective," pp. 102–3. Paris, 1899.

5 F. M. Feldhaus, "Die Technik der Antike und des Mittelalters," p. 25. Potsdam, 1931. M–H. Cornejo, "Sociologie générale," Vol. I, p. 415. Paris, 1911. A. Vierendeel, "Esquisse d'une Histoire de la Technique," Vol. I, pp. 11–12. Paris, 1921.

been dealt with in an atomistic and mechanical fashion, the fact that the correlation is concretely absent in many societies casts doubt on the proposition. Thus, Levasseur's criticism that certain provinces in China with a higher density than some areas in France should show more inventiveness than the latter if this theory were valid, applies only if density is treated as an *isolated factor* which *concretely* evokes the same result, whatever the social and cultural context. But, as will become evident, if population density is considered analytically as but one social element in a complex configuration and if its significance is correspondingly circumscribed, such strictures are no longer applicable.

In any event, a mere indication of this correlation does not by any means satisfactorily exhaust the problem. There still remains a description of the mechanisms and processes whereby this association is effected. In brief, what are the characteristics of a high population density which are apt to lead to increased technologic and scientific development?

The answers of the demographers to this question fall into two categories: an increase of the need for new inventions and an intensification of social interaction. The concept of sheer need as a precipitant of invention is very widely accepted despite the obvious limitations of the notion. Thus, W. I. Thomas has popularized the conception that a "crisis gives rise to invention."[6] This represents the familiar fallacy of generalizing a partial truth. Although, as Rossman has indicated, invention in military fields frequently responds to the stimulus of war needs,[7] and the *Atlantique* disaster resulted in inventions for the prevention of fire at sea, and the great flour-dust explosion in Minneapolis mills (May, 1878) resulted in *thirty* effective inventions for preventing the recurrence of such an accident,[8] it is equally true that a multitude of human "needs" have gone unsatisfied throughout the ages. Moreover, countries which are often considered to be the most needy of invention, such as Amazonia and India, have relatively little invention.[9] In the technical domain, "needs," far from being exceptional, are so general that this notion explains little. Each invention *de facto* satisfies a need or is an attempt to achieve such satisfaction.

Another consideration is pertinent. "Need" is an elliptic term which in the contexts considered always implies "realization or consciousness of need." In other words, where an observer from a culture which has a long tradition of attempts to improve material welfare and to control nature may often detect a "need" in another society, that need *may not exist* in terms of the values current in the culture which he is observing. This is the same kind of fallacy which is often implicit in the use of the concept, "culture lag," where it is maintained that a given situation "calls for" (*i.e.*, has a "need of") certain cultural changes. Such statements are valid only within certain value-contexts which *assume* that changes of a specific type are needed to effect an *imputed* goal. But it is only when the goal is actually part and parcel of the culture under consideration that one may properly speak of a need directing inventive interest in certain channels.

The fact is that need, in itself, is not sufficient to induce invention but acts only as a precipitating and directive

6 W. I. Thomas, "Source Book for Social Origins," pp. 13–26. Chicago, 1909.

7 Joseph Rossman, *American Journal of Sociology,* 1931, Vol. 36, pp. 625–33.

8 P. B. Pierce, *Transactions of the Anthropological Society of Washington,* 1885, Vol. 3, p. 165.

9 S. C. Gilfillan, "The Sociology of Invention," p. 48. Chicago, 1935.

influence if the social context is one which places a high value upon invention, which has a long history of successful invention and which customarily meets the given needs through technological invention rather than by other means of satisfaction. Thus, as Professor Sorokin points out, certain economic pressures may be met by migration of "surplus" population, by war, plundering and the like (as contemporary events illustrate). For example, military technology was substantially undeveloped by the Romans, their military supremacy resting primarily upon discipline. Thus, a need may be met through non-technologic means. But given the tradition of meeting these needs through technologic innovation, a tradition which is thoroughly ingrained in our Western culture; given the prerequisite accumulation of technical and scientific knowledge which provides a basic fund from which to derive means of meeting the given need; and it can be said that in a limited sense, necessity is the (foster) mother of invention.

Once these reservations are fully appreciated, it becomes evident why increased population density, by evoking new needs, does not inevitably facilitate invention. For this process to become effective it is necessary that the society be of the specific type we have described, with cultural values and accumulated civilizational products which not only make possible but largely determine an advancing rate of technologic development.

The second process through which population density is asserted to provoke advance in science and technology is that of increasing social interaction. But this very statement indicates that population density *as such* does not bear any uniform relation to scientific development, since variations in the degree of social interaction may be effected through means other than growing population. For example a sparsely settled area with highly developed means of communication and transportation may have a much higher degree of social interaction than such densely populated countries as China. Hence, since population density is in this sense an accidental concomitant of social interaction and indirectly of marked scientific development, it becomes an avowedly tenuous factor in such development.

Increasing population density may thus facilitate the advance of technology and science primarily in two ways: first, by evoking certain new needs (subject to the qualifications previously mentioned), which has the effect primarily of *directing* inventive interest in certain channels rather than of accelerating the rate of invention; and second, by inducing a higher estimation of inventive activity because of the greater economic value of invention among large populations. Another means through which the growing density of population is said to accelerate invention, namely, by increasing social interaction, does not necessarily arise from heightened density alone, and may hence be considered as a factor independent of the concentration of population.

A large population has a greater number of inventive minds than a smaller group (keeping ethnic factors constant) and it is the absolute number of such inventors, rather than their proportion to the entire population, which is of primary significance for the rate of innovation. But, on the other hand, the mere number of "potential" inventors will not notably affect the rate of invention unless there is free communication between the inventors, a system of cultural values which places a high estimation upon innovation and an accumulation of knowledge which is at the ready disposal of the would-be inventors. The

last two conditions are cultural and civilizational, respectively, and need not concern us here. But the first of these factors, the kind and extent of social interaction, is perhaps the most important *social* element in the rate of invention.

A high degree of social interaction involves a number of processes which facilitate cultural change generally, and development in science specifically. The direct interaction which is afforded by face-to-face contacts is no more important than the circulation of sentiments, opinions, theories and facts which is made possible by various means of communication. Thus, both travel and communication stimulate and foment cultural change. Conversely, the relative lack of interaction is associated with what Teggart calls "the processes which are manifested in fixity, persistence, stagnation and conventionality." In such instances there is an absence of those intrusive factors which disrupt crystallized ideas and invoke all manner of change. The escape from traditionalism and the willing acceptance of the new is closely related to the rate, number and intensity of contacts.

Obviously, the contact of mind with mind (within certain cultural contexts) tends to stimulate observation and originality. Ideas and experiences which would otherwise have remained strictly personal may, through the medium of interaction, became elements of innovation and discovery. Observations may be made by one scientist for which he has no explanation, and were these observations not communicated to other investigators they would then have no significance for scientific development. But once they are submitted to others for explanation, once there is social interaction, there is a possibility (which is more probable, the more minds there are in contact) that these observations can be unified and systematized by a theory.

Thus, Jean Richer went from Paris to Cayenne (French Guiana) in 1671 to make astronomical observations for the purpose of finding the longitude. He found that his pendulum clock which had kept correct time in Paris fell daily two and a half minutes behind mean solar time. The pendulum was shortened, but upon his return to Paris, Richer found that it was too short. He could not account for this phenomenon, but upon its being communicated to Huyghens, this brilliant theorist ascribed the phenomenon partially to the greater centrifugal tendency of the earth in Cayenne. Thus, Richer's observation, which, had it not been communicated to others, would have had no bearing for the contemporary scientific advance, led to the theory that the same body receives different accelerations by gravity at different places on the earth.[10]

Incidentally, this same experience furnishes an illustration of the complex interlocking of the sociological factors which affect science. It is true, as has just been indicated, that the explanation of this phenomenon was found as a result of interaction between Richer and Huyghens; an explanation worked out in detail in the latter's "Horologium Oscillatorium." But one may push the sociological analysis further and ask how it happened that the original observation could have been made by Richer, and independently by Halley. The answer to this query indicates the intervention of other social elements. The finding of the longitude was an aim constantly stimulated by the needs of navigation and ultimately of commerce. This led to numerous expeditions being financed by various governments for the

[10] Maximilien Marie, "Histoire des Sciences mathématiques et physiques," Vol. V, pp. 102–5. Paris, 1884.

determination of the longitudes of important places throughout the world. It was upon such expeditions that both Richer and Halley made their observations of the shortening of the pendulum near the equator. It thus becomes evident how, in an admittedly roundabout and complex fashion, social and cultural factors converged to make possible Huyghens's abstract theory of the differential acceleration by gravity according to position on the earth.

Perhaps one of the most noteworthy examples in which interaction led to the introduction into the stream of scientific development of ideas which otherwise might have remained private involves Newton's "Principia." As is well known, the greater part of Newton's thoughts on gravitation was completed in 1666. For various conjectural reasons, the most probable being that he had not yet been able to determine that the attraction of a spherical body was concentrated at its center,[11] Newton put his work aside. It was only after his and Dr. Donne's visit to Wren in 1677, and Hooke's letter of 24 November 1679 asking Newton to comment on Hooke's theory of celestial motions, that Newton temporarily returned to problems of gravitation.[12] And it was only that "Newton was stimulated by Halley's visit of 1684 to return to the whole question of gravity . . ." which resulted in the actual publication of the "Principia."

There are a number of other ways in which social interaction influences the development of science. The laws used in science are selected from a number of possible laws which adequately state uniformities between the observed facts. Hence, the selection can not be made solely upon the basis of sheer correspondence to the facts. In other words, in the selection of a law which is stated to be "true," its truth (correspondence to the facts) is a necessary, but not sufficient, condition of its selection. The law is ultimately found acceptable because it fits into a theoretical structure the form of which is determined by preconceived ideas of what a theory should be.[13] Thus, in the seventeenth century, both the undulatory and corpuscular theories of light adequately accounted for certain phenomena of light, but the authority of Newton's apparent rejection of the wave theory led to its abandonment for the next century. Or to take a modern instance, Einstein and Eddington have severally presented a development of the theory of relativity for the unification of gravitational and electrical phenomena which correspond to the facts equally well. In short, from among the various theories which satisfy the observations the one chosen is selected because of the intellectual satisfaction which it affords. But the criteria of what constitutes intellectual satisfaction in any given period arise largely from the cultural scheme of orientation.[14] Thus, scientific laws are seen to have two primary aspects: the first, which is congruence with observed facts, may be called, following Campbell, the objective "truth" of the law; and the second, the fact that it provides intellectual satisfaction, may be termed its "meaning."

But scientific truth, in this restricted sense, is a quality which signifies the same for others as for ourselves and of which, moreover, the scientist can only be privately, and hence, not scientifically,

[11] *Cf.* Florian Cajori, "Newton's twenty years' delay in announcing the law of gravitation," in "Sir Isaac Newton," pp. 127–91. Baltimore, 1928.

[12] W. W. R. Ball, "An Essay on Newton's Principia," pp. 140, 155. London, 1893.

[13] N. R. Campbell, "Physics, the Elements," p. 157. Cambridge, 1920.

[14] Erwin Schroedinger, "Science and the Human Temperament," pp. 96 *ff*. New York, 1935.

certain until it has met with acceptance by other qualified persons. It is this fact which is basic to Lancelot Hogben's publicist view-point. For science is public, and not private, knowledge; and although the idea of "other persons" is not employed explicitly in science, it is always implicit. In order to "prove" a theory, which for the individual scientist on the basis of his own private experience may have already became a "true law" which requires no further confirmation, the investigator is compelled to set up critical experiments which will satisfy the other scientists engaged in the same cooperative activity. This pressure for so working out a problem that the solution will satisfy not only the scientist's personal criteria of validity or adequacy, but also the criteria of the group of scientists with whom the investigator is actually or symbolically in contact, constitutes a powerful social impetus for cogent, rigorous scientific development. The work of the scientist is at every point influenced not only by the intrinsic requirements of the phenomena with which he is dealing, but more directly by his reacting to the inferred critical attitudes or actual criticism of other scientists and by an adjustment of his behavior in accordance with these attitudes.

Thus, Fahie cites Galileo as having written that "ignorance had been the best teacher he ever had, since in order to be able to demonstrate to his opponents the truth of his conclusions, he had been forced to prove them by a variety of experiments, though to satisfy his own mind alone he had never felt it necessary to make any."[15] Or, to take another instance, Boyle would probably never have discovered the law bearing his name were it not for the criticism of his "New Experiments . . . touching the Spring of the Air" made by Franciscus Linus. Linus, in examining Boyle's work, declared that the air is definitely insufficient to achieve such great effects as counterpoising a mercurial cylinder of twenty-nine inches. Linus maintained that the mercury hangs by invisible threads (funiculi) from the upper end of the tube. This criticism incited Boyle to renewed research, which finally led to the experimental validation of the theory "that supposes the pressures and expansions of gases to be in reciprocal proportion."[16]

The history of the establishment of this law also illustrates another consequence of social interaction which we have previously discussed; namely, the provision of new contexts which render significant previously meaningless observations. Hooke had in 1660 made similar experiments upon the rarefaction of the air, but he did not organize these results into any coherent theory. It was only in the following year, when he heard of Boyle's hypothesis, that he repeated these experiments over a greater range with results substantially verifying the theory. In other words, the meaningfulness of mere observation resulted from a hypothesis derived from contact with contemporary scientists.

The rôle of criticism is further illustrated by Hooke's animadversions upon Newton's theory of light, which resulted in the latter submitting a large number of considerations which he had not raised in his initial papers. Newton was compelled to institute a number of additional experiments to test aspects of his theory which he had not previously considered.

[15] J. J. Fahie, "The Scientific Works of Galileo," in "Studies in the History and Method of Science" (ed. by Charles Singer), Vol. II, p. 251. Oxford, 1921.

[16] Robert Boyle, "New Experiments Physico-Mechanicall, touching the Spring of the Air, whereunto is added A Defence of the Author's Explication of Franciscus Linus and Thomas Hobbes," p. 100. Oxford, 1662. The title of this book indicates the effectiveness of criticism in evoking continued and more rigorously executed research. *Cf.* Florian Cajori, "A History of Physics," p. 73. New York, 1924.

In this sense is conflict the "gadfly of thought."

A telling indication of this process is found in the fact that scientific theories and laws are presented in a rigorously logical and "scientific" fashion (in accordance with the rules of evidence current at the time) and *not* in the order in which the theory or law was derived. This is to say, long after the theory has been found acceptable by the individual scientist on the basis of his *private* experience he must continue to devise a "proof" or "demonstration" in terms of the approved canons of scientific verification present in his culture. As Poincaré has indicated, most important scientific discoveries have been divined before they have been demonstrated. But intuition, howsoever powerful an instrument of invention it may be, is never a sufficient basis for a doctrine to become incorporated as a part of science. "Demonstration" is still necessary.

Jean Piaget has described the differences between one's private way of developing his thoughts and the order in which they are presented to others.[17] The logical and empirical ramifications of a doctrine must be worked out before it is accepted by others; implications must be pursued far beyond the point where an individual, not in contact with similarly equipped critics, might be content to rest his analysis. In this way, social interaction provides a definite incentive for highly rigorous scientific investigation. As Piaget has observed, children gradually learn to socialize their beliefs by logical and factual proof only as a result of conflicts of opinion between them. When simple affirmations or denials are seen, through a series of disconcerting experiences, to possess no cogency, "reasons" are gradually submitted to justify their beliefs. On a higher plane, as is evidenced in the previously cited illustrations, the same process is found in scientific development. The greater the number of critical minds surveying the evidence the more exacting is the compulsion to work out the ramifications of a theory so that it will become scientifically acceptable.

To summarize, one may say that a high degree of social interaction tends to foment rebellion against traditionalism and to make for the willing acceptance of novelties and innovations. It tends further to enhance scientific development by increasing the probability that scattered observations will be unified by some generalizing theory. Finally, criticism (as one form of social interaction) increases the pressure upon scientists for methodically following through the implications of their theories beyond the point where they may have felt personally content with their research. In this way, the rate of scientific development is materially increased and the resulting theoretic structure maintains a high degree of inner consistency and coherence.

THE INTERNATIONAL MISSION OF SCIENCE

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If there is anything objective in human nature, it must be science; if there is anything in this world that does not stop at national or military frontiers, it is the scientific thirst for the conquest of the unknown, the scientific curiosity to look behind the stage of life and to solve the mystery of the cosmos.

[17] Jean Piaget, "Judgment and Reasoning in the Child," Chaps. V, IX. London, 1929.

This is, of course, an assertion, and we shall have to prove it. Let us consider, then, some of the reasons why science should be objective. First of all, the subject of science is independent of any individual or nation. If it is found by an Englishman that light and radio waves are essentially the same phenomena, any one on earth might repeat the crucial experiments and will obtain the same results under similar conditions. Let me emphasize the same result. Where in any other occupation of the mind, be it religion, philosophy, law, economics or even the social sciences, can this be said? But more, the most standardized language on earth is mathematics, and just mathematics is the universal means of expressing scientific truths. Be it in the form of a theory or in the form of quantitative experiments, the mathematical relations form the backbone of true science. In fact, it is even presumed at times that nothing should be called science unless it could be brought into the form of mathematical relations. This may, of course, be going too far. Nevertheless, it indicates that the method of scientific investigation is the same in all countries and for all individuals. A third reason, and the final one I shall consider here, is the fact that scientific knowledge has grown to such vast proportions that it is humanly impossible for any one man to master all of it. Any scientist interested in a particular subject, who sets out to do research, must inevitably study first what has been done in this field. Without this information, he might spend a lifetime trying to reestablish discarded theories or to rediscover what others had found long before him. It is necessary for a scientist to study not only the local, but the world literature in order to keep abreast of the events. But this means continued contact with foreign publications, as well as with the national ones. It means cosmopolitan interests as against national interests. And it means, most important of all, admiration for the progress of scientific thought and discoveries in other countries and, connected with it, a deep admiration for the achievements of the human mind.

Thus we find three phases in scientific endeavor which tend to make science truly objective: the subject itself, the method of pursuit and the study of progress of science. But—you could raise these questions—are not scientists to be thought of as individuals of a particular nation, bound by tradition and inheritance to be prejudiced in favor of their own nation? Will they, in case of war, not be acclaiming their own nation and denouncing the enemy nation? And I must answer: Yes, scientists fought in the last world war under all flags, and probably will do so again in a future war. As individuals, they can not escape the national bonds, the bonds of the larger family they happen to be born in. Scientists are not superhuman beings, but they are the qualified missionaries for international understanding which is progressing, as I optimistically might say, despite recent events. The continued occupation with science of one group of individuals in every nation can not but influence and in this way broaden the point of view of its other groups in the direction of international good will. The immense fertilization of objective ideas will eventually lead to a true League of Nations based upon mutual respect rather than mutual distrust.

Let me give you some reasons for my optimism by illustrating the international cooperation of science toward a common goal. The tremendous upswing in scientific development started in 1820 with the accidental discovery by the Danish scientist Oersted that an electric current will deviate a magnetic needle into a definite direction. Up to that time no one had ever thought of electricity or magnetism as other than entirely unre-

lated playthings, to amuse people. The new experiments, however, connected electricity with magnetism. About fifty years of research, in which the scientists of all countries participated, brought electricity into the household, made it indispensable in factories and introduced names familiar to every one, such as the Frenchman Ampere, the Italian Volta, the Englishman Faraday, the German Ohm, the American Henry, and others.

But science did not stop there. Once it had given the world the basis for undreamed-of engineering projects, it moved on into the deeper jungles of electromagnetic phenomena. Again, scientists of all countries attacked at once the phenomenon of light, and discovered in less than forty years what Sir William Bragg so aptly called the "universe of light." For a short time it had been thought possible to explain light as a particular case of radio waves of extremely short wave-lengths. But to-day it seems more reasonable to assume that all radiation is of the same type as light, that radio waves, heat radiation, ultraviolet, infra-red and x-rays, even the cosmic rays, are all but different aspects of the same fundamental phenomena. Unity displayed in the amazing diversity! Simplicity hidden behind the confusing variety of radiations with so many different effects!

Perhaps this should serve us as a warning. Perhaps this should illustrate to us some law of nature in producing many human races and nations instead of a single standardized international human being. The "universe of light" might be comparable to humanity, and the various kinds of radiation to the different nations. Without the variety of radiations, indeed, life could not exist on earth in its present form. Without the different characteristics of the kaleidoscopic nations we probably could not succeed so quickly and so well in advancing our scientific knowledge, because—and this is a fundamental truth—mankind needs stimulation, and variety of view-points, in order to incite those flashes of genius that mark the large steps forward. In exploring the nature of radiation, the Germans Planck and Schroedinger, the Englishmen Maxwell and Rutherford, the Dane Bohr, the Frenchman de Broglie, the Americans A. H. Compton and Millikan, to name just a few of the most outstanding ones, had to contribute in succession and alternately in order to build the "universe of light."

The rapid development of scientific knowledge, which we witness to-day, is not only due to better methods, but has also been the result of an accelerating pace because of the increasing number of scientifically trained people. Thus, as time goes on, larger groups within the nations take part and are interested in scientific research, transcending in this manner the national bonds at least temporarily, and gaining respect and appreciation for the achievements of other nations.

It is obvious, then, that science has a true international mission. Far from choosing propagandistic methods to promote internationalism, science creates the true atmosphere of humanity as a common bond of the many diversified races and nations, just as the universe of radiation is the super unit of light and heat, of death rays and life rays. As it is important to recognize the facts and advantages of racial and national differences, so it is equally important to consider nationalism only as a first step towards true international understanding, based upon respect and appreciation for the services of each individual nation to humanity.

INSECT TRANSMISSION OF VIRUS DISEASES OF PLANTS

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No group of plant diseases has attracted as much attention in recent years as those caused by viruses. A half century ago we did not recognize a half dozen distinct diseases which are now attributed to viruses. We did not know their causes and very little about their character. To-day we know that more than a thousand species and varieties of plants are subject to these diseases. We call them virus diseases, but we do not know with certainty the character of the active agents causing them, though we do know some of the properties of these active agents. We do not know with any degree of accuracy the number of distinct so-called viruses or active agents causing these diseases in this long list of host plants, but we do know that they are the causes of heavy losses in our agricultural crops.

All students of the subject recognize the importance of knowing more about the causal agents of these diseases. One of the most important phases of the subject is a knowledge of the methods of transmission of the causal agents from plant to plant and from locality to locality in nature if we are to control them and reduce these heavy losses to the minimum. The early students of these diseases were not slow to find that the causal agents could be transmitted by inoculation with juices and by budding and grafting. Some years later it was learned that some of them are transmitted by cuttings, tubers and bulbs from diseased plants. The early students announced that the diseases studied by them were not transmitted by seeds from diseased plants, but later studies have shown that a considerable number of them are transmitted in this manner, although in some cases the percentage is extremely small.

Probably the most important discovery was that some of them were transmitted by insects. This discovery was not made in a day. In fact, there was an interval of fifteen or twenty years from the time when insects were first recognized as probable carriers until the importance of this method of transmission was demonstrated. Since that time our knowledge of this method of transmission has increased very rapidly and we now recognize more than 135 species of insects as vectors of these diseases.

Smee of England (1846) reported that *Aphis vastator* was very abundant on potatoes with "curl," which was probably a virus disease, but this announcement did not attract any attention. Woods (1897) called attention to the presence of aphids associated with the Bermuda lily disease, which is now known to be due to a virus, but he believed that the insects caused a starvation of the plants and that the disease was due to an increase in the amount of enzymes.

It is interesting to note that the two discoveries which led to our present knowledge of the relationship of insects to virus diseases were made before our present ideas of the causes of these diseases had been developed. The first students of this phase of the subject believed that the insects were the causes of the diseases.

The first records that are at all definite in regard to the transmission of virus diseases by insects that have come to the attention of the writer are those concerning the "dwarf of rice" in Japan and the

"curly top of sugar beets" in the United States.

It appears that Hashimoto (1894–95), a Japanese farmer, was the first to prove experimentally the relationship of leafhoppers to the dwarf disease of the rice plant, but he did not publish any of his data.

Takata (1895–96) was the first to write on the causal relationship of the leafhoppers. He stated that the leafhopper was known as "mon-yokobai," which was probably *Deltocephalus dorsalis* Motsch, but his determination of the insect was evidently an error. These two men should have the credit of this discovery, although they did not understand the cause of the disease and the determination of the vector was incorrect.

A brief note in the *Official Gazette* of the Japanese Government (1890) states that the leafhoppers were abundant on the rice plants in localities where the disease was prevalent.

Report I (1897) of the Shiga Agricultural Experiment Station mentions several leafhoppers as causing the dwarf disease of the rice plant, but Report II (1900) states that only one species, *Nephotettix apicalis* Motsch var. *cincticeps* was the true cause.

Takama[1] summarized the work of this experiment station and concluded that the disease was due to this insect. It was later (1906) demonstrated that the insects from some parts of Japan would produce the disease, while those from other parts would not do so. This was confirmed two years later. Still later it was proved that all of them would produce the disease if fed on diseased plants and then transferred to healthy plants.

The Imperial Agricultural Experiment Station at Tokyo was the first to prove (1906) that *Nephotettix apicalis* var. *cincticeps* did not cause the disease but was the carrier of the active agent that caused it. The Shiga Agricultural Experiment Station confirmed this work and was the first to report it (1908). The writer has not been able to learn the names of the persons who demonstrated the proof and made the report.

The Japanese name of the insect is "tsumagoro-yokobai," and it was described in 1896 by Uhler under the name *Seleocephalus cincticeps*.[2] Matsumura considered it a variety of *Nephotettix apicalis* which he had previously established.[3] It was originally described in India by Motsch as *Pediopsis apicalis* in 1859.[4]

The first virus disease of plants in America that was proved to be carried by an insect was curly top of the sugar beets. This disease was reported on sugar beets in California about 1899 and came to be so injurious to the crop that it attracted a great deal of attention and was the subject of study by several American scientists. It is very evident that the disease came from wild plants, which are now known to be susceptible. The history of our knowledge of the transmission of this disease by an insect is briefly as follows.

Townsend (1902) described the symptoms of the disease. R. E. Smith (1906) stated that it was a definite disease and the result of unfavorable environmental conditions. Ball (1906) called attention to the large number of *Eutettix tenella* Baker and said that its punctures "seemed to cause a sort of thickening of the veins of the leaf and an unhealthy condition called curly leaf or blight."

Ball (1907) suggested that the disease might be similar to galls of plants which are caused by insects.

Townsend (1908) called attention to the presence of *E. tenellus* on growing sugar beets and said that the growers believed these insects to be the cause of the curly top disease. He also called attention to the insect feeding on *Rumex crispus*. The insect is now known to feed

[1] *Jour. Agr. Soc.*, 241: 22–30, 1901.

[2] Proc. U. S. National Museum 1896, p. 292.

[3] Trans. Sapporo Nat. Hist. Soc. 1905, p. 20.

[4] Etude Ent. 1859, p. 110.

on several species of wild plants which have been proved to be susceptible to the curly top disease.

Ball (1909) published the results of observations and experiments made in 1905 and 1906. He said:

> As a result of the season's observations there seems to be little question that the "curly leaf" condition was result of the attack of the leafhopper combined with the effect of a very hot, early season. . . .
>
> In the case of the "curly leaf," however, the abnormal condition apparently spreads from leaf to leaf until finally the whole plant is affected, even though the leafhoppers may have disappeared before the process is complete.

Ball (1909) reported cage experiments for the study of the life history of the insect. The beet plants in two of these cages died in a short time.

Adams (1909) records the putting of four *E. tenella* in a cage with a healthy beet plant, which developed the disease later.

Spisar (1910) expressed the opinion that the disease was not caused by the punctures of the insect, but agreed with Ball, who had previously expressed the opinion that the abnormalities were due to something which the insect injected into the plant.

Shaw (1910) reported the result of cage experiments in which he found that the leafhoppers from the western regions in which the disease occurred could produce the disease in sugar beets grown in cages in Washington, D. C., where the disease did not occur. He believed that the insects were the cause of the disease and that it did not exist outside the range of the insect. He did not know the cause of the disease, but suggested that it might be due to some active agents injected into the plant by the insect.

The results of Ball, Adams and Shaw in their cage experiments were confirmed by R. E. Smith and Boncquet (1915), who demonstrated that a single insect from a diseased plant placed on a healthy plant for five minutes would result in the development of the disease. They concluded that it was possible for the insect to extract the active agent from a diseased plant in three hours, but that 24 to 48 hours must elapse before the insect could transmit this agent into a healthy beet plant. This work indicated that the disease was not due to insect injuries, but they did not say anything about a virus. A little later in the year, Boncquet and Hartung reported that the insects collected from *Artemisia* or *Atroplex* of the upper Joaquin valley did not produce the disease, while those from diseased beets at Spreckels, California, did transmit the disease to healthy plants. They also demonstrated that when these insects from healthy plants were transferred to diseased beets for a time and then returned to healthy plants, the disease appeared in due time. This was a very definite demonstration that the leafhoppers were the carriers of the active agent of the disease.

Up to this time our ideas as to the cause of this disease were very indefinite, as shown by the following statement in a paper by Boncquet and Stahl (1917):

> The curly-top condition of sugar beets has for some time been a subject of investigation by phytopathologists, but on account of the failure to discover a specific organism responsible for the physiological injury to the plant, the problem has been peculiarly baffling. Although the connection of the jassid leafhopper, *Eutettix tenella* Baker, with the disturbance has been definitely established, conclusive evidence has not been available as to the exact nature of the trouble, or as to the part played by the leafhopper in the dissemination of the virus.

Ball (1917) published a bulletin in which he reviewed our knowledge of the entire subject. Some of his comments which are quoted below show the extent of our knowledge of the subject at that time. He said:

> There are a large number of plant diseases for which no causal organism has as yet been found, curly leaf among the number. . . .
>
> A puncture of the beet leafhopper is absolutely necessary to cause the disease to develop

in the beet. Under favorable conditions Titus found that a very short application of a single insect would produce the disease on a young beet. . . .

The disease never spreads from beet to beet except as it is transmitted by the leafhopper. . . .

The punctures of the beet leafhopper (*Eutettix tenella* Baker) cause a specific disease of the sugar beets called "curly leaf." . . .

Curly leaf has never been produced except through the punctures of a beet leafhopper.

Within the last fifteen or twenty years it has been demonstrated that the virus of this disease will attack tomatoes, beans, squashes and many wild plants. The insects feed on these hosts and transmit the disease from species to species. It appears that the insects pass the winter on some of the susceptible wild host plants and travel from them to the young crop of sugar beets, carrying the active agent which causes the disease.

A study of the literature on these two diseases indicates that the early workers believed that the insects were the causes. However, the work of Takata and Ball demonstrated the importance of the study of insects in connection with this great group of diseases which are now known as virus diseases.

Clinton and Allard called attention to the presence of insects on diseased plants, and in 1916 Doolittle and Jagger, working independently, demonstrated that *Aphis gossypii* was a carrier of the cucumber mosaic. From that time to the present studies of this kind have been very fruitful and it has been found that about 150 species of insects are carriers of virus diseases. Some of them carry but one virus so far as known, while others carry several viruses. Records up to the present time indicate that *Myzus persicae* is capable of carrying more viruses than any other species.

These studies have been expanded and many interesting facts brought to light which can not receive more than a brief mention at this time.

It is well known that some insects are mechanical carriers; *i.e.*, the virus is smeared on the mouth parts while feeding on diseased plants and then rubbed off while feeding on a healthy plant. In most cases the virus is sucked up into the insect and then injected into the healthy plant. It is not known whether the virus undergoes a change in the insect or not, but there is evidence that it does increase in amount.

Stahl and Carsner (1918) and Severin (1922) reported that *E. tenellus* did not transmit curly top virus to its offspring. McClintock and Smith (1918) reported the transmission of the spinach blight through four generations of *Myzus persicae* and *Macrosiphum gei,* but Hoggan (1930) failed to confirm these results with cucumber mosaic, which she found to be one of the three viruses causing the spinach blight. It is possible that McClintock and Smith used one of the other two viruses. Fukushi (1933) reported the transmission of the virus of dwarf disease of rice from parent to offspring through the egg of *Nephotettix apicalis* var. *cincticeps.* This is the first definite record of this kind.

Kenneth M. Smith, of England (1928), discovered that when a potato mosaic with which he was working was transmitted by needle punctures to a healthy tobacco plant the symptoms were different from those that developed when the transmission was made by means of *Myzus persicae.* It was found that this mosaic was the result of a mixture of two viruses, both of which were transmitted by the needle inoculations and only one by the insect inoculations. Hoggan (1930) reported that *Myzus pseudosolani* and *Macrosiphum solanifolii* (*M. gei*) were able to transmit tobacco mosaic virus from tomato to many solanaceous plants but not from tobacco; that *Myzus circumflexus* was able to transmit the virus from tobacco. These studies indicate that some viruses may be isolated by the insect vectors and that this may be an important factor in the classification of viruses.

CHANGES IN NERVE FIBERS DURING ALCOHOLIC INTOXICATION AND RECOVERY[1]

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Throughout the ages alcoholic drinks have been popular with mankind. Recent events in this country strongly suggest that this popularity is not on the wane.

Alcoholic intoxication is accompanied by certain definite symptoms familiar to every one. The sensory mechanism, the motor mechanism, the coordinating mechanism and the mental processes are all affected. All these mechanisms are known to be intimately related to the proper functioning of nerve cells. It is beyond doubt, therefore, that alcohol must act upon the nervous system.

The *functional* disturbances associated with alcoholism have been rather thoroughly studied. The *structural* disturbances, however, have never been satisfactorily investigated. Martland[2] tersely sums up the subject with the statement that "extensive permanent injury to the cells of the brain, spinal cord and nerves is, on the whole, unusual or at least does not appear on a gross and microscopic study of the tissues after death." He, nevertheless, considers that alcohol produces its main damage in the nervous system.

For several years, I have been watching the behavior of nerves in living organisms by direct observation. Small frog tadpoles are used. An animal is slightly anesthetized and placed on a specially prepared microscopic slide. Individual nerve fibers are then observed in the transparent tail fin under very high magnification. A map of the nerves is made, the animal replaced in pond water and on the next day the same region and the same nerves are again studied. By this method histories of individual nerve fibers over a period of several months may be obtained. Thus the growth of nerve sprouts, the formation of the nerve sheaths and the changes during nerve injury and repair have all been seen in the living tadpole.[3]

It occurred to me that it might be interesting to watch nerve fibers while the tadpole was subjected to prolonged and repeated intoxication by alcohol. This proved to be entirely feasible. My records now include many case histories of nerve fibers which demonstrate that practically all graduations of irritation and injury may be induced by alcohol treatment. Illustrative motion pictures showing such irritated nerve fibers have also been made directly from the living animals.

Before describing a few of these cases, the following points may be noted. Poisoning of nerve cells by alcohol depends upon the concentration of alcohol in the blood and body fluids. It matters little as to the mode of entrance. In the tadpole, the alcohol is administered by way of the skin. The moist skin of the frog tadpole is readily permeable to alcohol, being comparable in this respect to the lining of the alimentary tube of man.

Fortunately, the nerves of the frog

[1] Complete details of this study have been published in the *Journal of Comparative Neurology*, Vol. 64, under the title "Studies of Living Nerves. V. Alcoholic Neuritis and Recovery."

[2] In chapter IX of "Alcohol and Man," edited by H. Emerson.

[3] Details are published in the *Journal of Experimental Zoology*, Vol. 61; *American Journal of Anatomy*, Vol. 52; *Journal of Comparative Neurology*, Vol. 61, and the *Biological Bulletin*, Vol. 68.

tadpole are constructed essentially on the same plan as those of man. Single mature fibers of the type which bring in sensation from the skin are readily available for observation. The chief parts of such a fiber are shown in the diagram (Fig. 1, a). A conspicuous feature is the myelin sheath, a fatty covering which encases the nerve axis and protects, insulates and nourishes it. This sheath is in the form of segments separated by constricted nodes, the arrangement resembling a string of sausages. As it responds quickly to irritation of almost any sort, it is an excellent indicator of alcohol effects. It may swell greatly, degenerate or partially degenerate, even though the nerve axis cylinder within remains alive (Fig. 1, b, c, d). It never persists, however, if the axis cylinder degenerates.

Outside the myelin sheath near the middle of each segment lies the sheath cell nucleus. A very delicate membrane (called the neurilemma), which is a part of the sheath cell, forms a tubular covering for the nerve fiber. It is not in segments like the myelin sheath, but extends from segment to segment over the nodes as a continuous membrane. It is best seen as the myelin sheath fragments (Fig. 1, d).

Answers were sought to the following questions:

(1) Exactly what structural modifications take place in nerves during alcoholic intoxication?

(2) What are the steps of recovery after both mild and severe cases of intoxication?

(3) Can complete degeneration of myelin sheath segments be induced?

(4) Does repeated alcoholic intoxication stop the addition of new myelin sheath segments in a growing zone?

(5) What are the relative effects of a single prolonged continuous period of strong intoxication (the "spree" type) and of short daily periods of mild intoxication continued, however, for many weeks?

(6) Does repeated alcoholic intoxication stop growth of nerve sprouts?

(7) How do nerve endings react during various degrees of alcoholic intoxication and recovery?

Effects of alcohol on myelinated nerve fibers: In very dilute alcohol (less than 0.5 per cent.) tadpoles may live indefinitely with little or no indication of any special nerve irritation. In much stronger alcohol solutions (more than 3 per cent.) death usually ensues within a few hours. The skin suffers direct injury in these.

Alcohol solutions in the neighborhood of 2 per cent. are very effective in bringing on marked nerve changes.[4] A strongly irritated nerve fiber exhibits the following changes (Fig. 1, b, c, d): marked swelling, undulating movements of the myelin sheath, appearance of watery spaces between the myelin sheath and the enclosed nerve axis, followed by gradual separation of these structures, assumption of an irregular wavy course by the nerve axis, and in extreme cases, degeneration of the myelin segment with the formation of myelin globules and ovoids. Similar changes in nerve fibers take place in tadpoles treated with wood alcohol.

Recovery quickly follows the milder treatments with alcohol. Irritated fibers which reach the stage shown in Fig. 1, b, usually recover completely in one or two days. A few small myelin globules may be pinched off from the sheath.

A fiber which reaches the greatly swollen stage shown in Fig. 1, c, usually recovers completely in two to five days. During the recovery the swelling subsides as fluid is expelled. Several myelin ovoids may be formed, each of which

[4] The effect of a given percentage of alcohol varies somewhat, depending on the age, size and species of tadpole. Older animals are less susceptible.

later may break up into smaller globules. Such a recovering fiber is shown in Fig. 1, e. Occasionally, however, a swollen myelin segment (such as that of Fig. 1, c) fails to recover and suffers subsequent degeneration (Fig. 3, segments R and S). In such cases a completely new segment may be regenerated. New myelin is formed through the cooperation of the sheath cell and the nerve fiber.

Myelin segments which reach the beaded stage of irritation shown in Fig. 1, d, usually degenerate completely or partially.

A number of tadpoles have been watched to see how nerves react to alcoholic intoxication of brief duration repeated each day for many days. Even strong doses which cause visible irritation do not necessarily cause permanent injury. Ready recovery may take place. In some instances the older segments of the sheath may become somewhat creased and wrinkled, a condition which probably indicates slight chronic irritation.

One interesting case may be cited in detail (Fig. 2). A tadpole became strongly intoxicated after living in 2 per cent. alcohol for 21 hours. Two of the last myelin sheath segments of a nerve fiber started to degenerate. On replacement of the animal in pond water, however, these segments recovered in a few days. Two more strong treatments were given at 2-day intervals. Thereafter, for a period of 75 days, the animal received enough alcohol once a day to stun it slightly. Temporary irritation of the fiber was usually visible during these treatments. However, the fiber readily recovered each day between treatments and remained fairly normal in appearance. Moreover, the youngest myelin segments grew some in both length and thickness. Some new nerve sprouts were also formed and three new segments were added near the end of the fiber. This case and others of similar nature suggest that daily intoxication of brief duration is not enough to cause degeneration of either myelin sheath or nerve axis. Nor is it sufficient to prevent the growth of nerves in regenerating zones.

On the other hand, a single severe prolonged treatment may cause marked injury of nerves, especially toward the tips. In one case an animal was kept in 2.5 per cent. alcohol for five hours. At the end of this period it was dazed ("dead drunk," in other words) and could be examined without the use of any anesthetic. The speed of the circulating blood was markedly less than normal. A long nerve fiber was observed with its myelin sheath in process of degeneration (Fig. 3). The last 13 myelin segments (that is, those nearest the tip of the nerve) were already breaking up into fragments. Those farthest from the nerve tip were all greatly swollen and exhibited definite separation of the myelin sheath from the nerve axis. The animal was then taken from the alcohol solution and put back in pond water and the process of recovery watched. During the next two days, two more of the swollen myelin segments[5] broke up into fatty ovoids. The others slowly recovered. At many points on these recovering segments, however, small myelin globules were cut off, an indication of the strong irritation to which the nerve fiber had been subjected. During the next two months, new nerve sprouts grew from the injured fiber to make entirely new connections with the skin.

Many attempts were made to induce degeneration of all myelin segments along a fiber. These invariably failed.

[5] In man, the day after a "spree" is often characterized by a headache. In tadpoles 12 to 24 hours after a period of severe alcoholic intoxication, many myelinated fibers are swollen to twice their normal diameter. If such a condition also obtained in the brain and spinal cord there would probably be a certain amount of compression. The headache of "hangover" day thus might be directly ascribable to this characteristic swelling of myelinated fibers.

Death of the animal ensued before fragmentation of the more proximal myelin segments of the fiber. Probably the treatments caused injury to some part of the nervous system associated with control of a vital activity, such as the heart beat.

This property of nerve fibers to degenerate peripherally is of interest. In cases of human alcoholic neuritis, as well as in various other forms of multiple neuritis, there is a loss or impairment of nerve function first near the nerve tips. The sensory and motor functions of the limbs are particularly disturbed; also, though to a less degree, those of the arms. My observations on alcoholic nerve irritation in tadpoles agree with this and give direct visual evidence that degeneration starts near the nerve tips and progresses centrally. Thus there is close correlation between the anatomical effects and the clinical symptoms.

Effects of alcohol on the growing tips of regenerating nerve fibers: When a nerve fiber is cut it regenerates. The peripheral part degenerates and is lost. The central part develops at its tip a "growth cone," which progresses by a slow flowing motion through the tissues spinning a fiber behind it. These growing tips are easily affected by adverse conditions. When alcohol treatment is given, a growing tip may retract quickly. After normal conditions are restored the nerve tip may again within 10 or 15 minutes resume its growth. In the example given (Fig. 4) growth, retraction and recovery are all shown. In this case and in other cases, about a half hour's treatment with alcohol was sufficient to cause a regenerating nerve tip to retract a distance of about one thousandth of an inch. The rate of extension of the nerve tip during recovery was somewhat less. About an hour was often required for growth equal to one thousandth of an inch. Motion pictures of the "fast motion" type reveal in dramatic fashion the

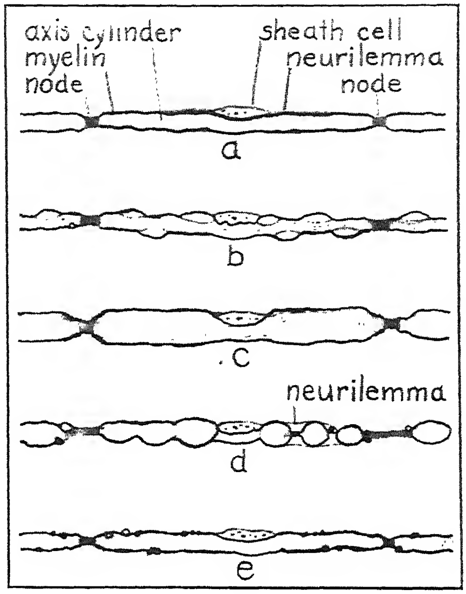


FIG. 1. CHANGES IN A NERVE FIBER OF A FROG TADPOLE DURING ALCOHOLIC INTOXICATION AND RECOVERY.

a, NORMAL APPEARANCE OF A SINGLE NERVE FIBER SHOWING THE POSITION OF THE AXIS CYLINDER, MYELIN SHEATH, SHEATH CELL, NEURILEMMA AND NODE BETWEEN THE MYELIN SEGMENTS. *b*, DURING EARLY STAGES OF MODERATE IRRITATION WATERY SPACES APPEAR BETWEEN THE MYELIN SHEATH AND AXIS CYLINDER. SMALL MYELIN GLOBULES MAY BE CUT OFF FROM THE SHEATH. *c*, A LATER AND GREATER DEGREE OF IRRITATION IS CHARACTERIZED BY MARKED SWELLING. *d*, EXTREME IRRITATION IS CHARACTERIZED BY FRAGMENTATION OF THE MYELIN INTO OVOIDS. THE DELICATE OUTER SHEATH (NEURILEMMA) IS OFTEN CLEARLY VISIBLE AT SUCH A STAGE. *e*, APPEARANCE OF A RECOVERING FIBER TWO DAYS AFTER STRONG IRRITATION. A FEW SMALL GRANULES OF MYELIN DEBRIS ARE THE ONLY INDICATION OF THE PREVIOUS IRRITATION.

retraction of nerve tips in alcoholized tadpoles and the subsequent growth during recovery.

These reactions are very conspicuous. They are important also because in somewhat exaggerated form they give a fairly good picture of what takes place sometimes at the nerve endings of resting nerve fibers.

Effect of alcohol on nerve endings: In

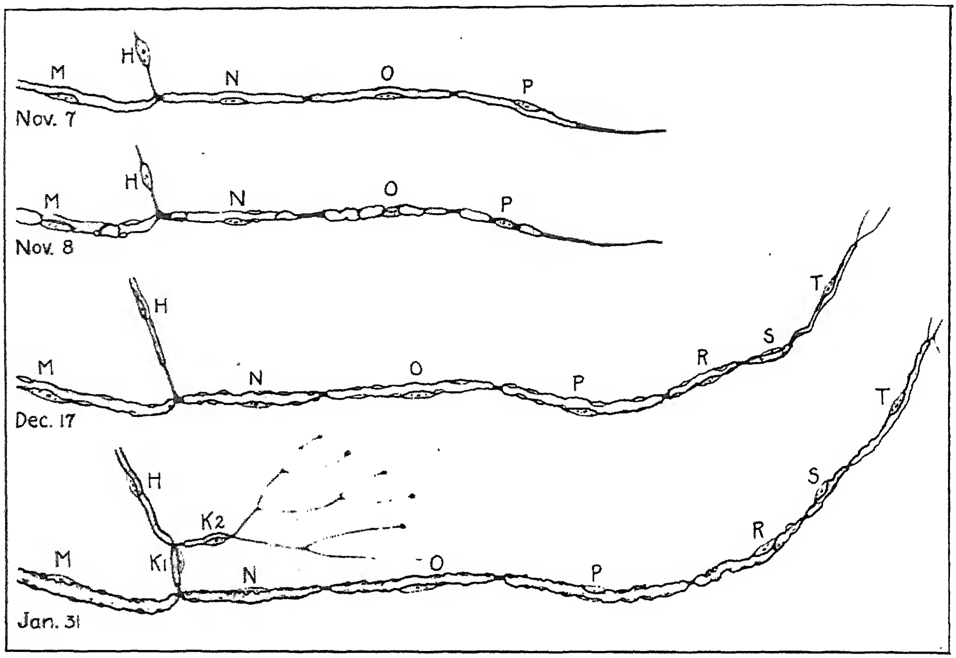


FIG. 2. EFFECTS OF DAILY ALCOHOL TREATMENT FOR A PERIOD OF NEARLY THREE MONTHS.

ON NOVEMBER 7 A TADPOLE WAS IMMERSED IN 2 PER CENT. ALCOHOL FOR 21 HOURS. A FIBER, OF NORMAL APPEARANCE BEFORE THE TREATMENT, BECAME MARKEDLY IRRITATED. ON NOVEMBER 8 WHEN THE ANIMAL WAS REPLACED IN WATER THE MYELIN SEGMENTS WERE SWOLLEN AND THE LAST TWO WERE IN PROCESS OF BREAKING UP. NEVERTHELESS, ALL THE MYELIN UNITS RECOVERED WITHIN A FEW DAYS. SIMILAR TREATMENTS WERE GIVEN ON NOVEMBER 14 AND NOVEMBER 16 WITH SIMILAR RESULTS. THEN FROM NOVEMBER 18 TO FEBRUARY 1 THE TADPOLE RECEIVED ENOUGH ALCOHOL ONCE A DAY TO STUN IT SLIGHTLY. EACH DAY DURING THE TREATMENT VISIBLE CHANGES OF IRRITATION OCCURRED (*i.e.*, VACUOLATION, SWELLING AND THE CUTTING OFF OF SMALL MYELIN GLOBULES). NEVERTHELESS, THE FIBER SLOWLY GREW AND NEW MYELIN SEGMENTS WERE ADDED. THREE OF THESE (SEGMENTS R, S AND T) WERE NEAR THE END OF THE FIBER; THREE (SEGMENTS K_1, K_2 AND H) WERE ALONG A COLLATERAL BRANCH.

the frog tadpole the ordinary sensory nerve endings in the skin are naked. As a myelinated fiber approaches its termination it loses its sheaths, *i.e.*, both the myelin sheath and the neurilemma. It branches freely and ends in about 15 to 30 tiny spherical or ovoid bulbs. These are located just beneath the basement membrane of the epidermis, which is the outer covering of the skin. On the whole, they are fairly stable structures. I have watched many of them for days or weeks during which no essential changes took place. Occasionally, however, a change of either growth or retraction may occur.

Careful observation reveals that decided effects may be discerned in these as a direct result of alcohol treatment. A typical case is illustrated (Fig. 5). With suitable strengths of alcohol there may be induced swelling, retraction and sometimes nerve autotomy[6] (*i.e.*, the self-

[6] If a lobster is held by one of its appendages, so that it is unable to get away, the appendage may be pinched off, thus freeing the lobster. This ability of an animal to separate itself from one of its limbs is called autotomy. Nerve

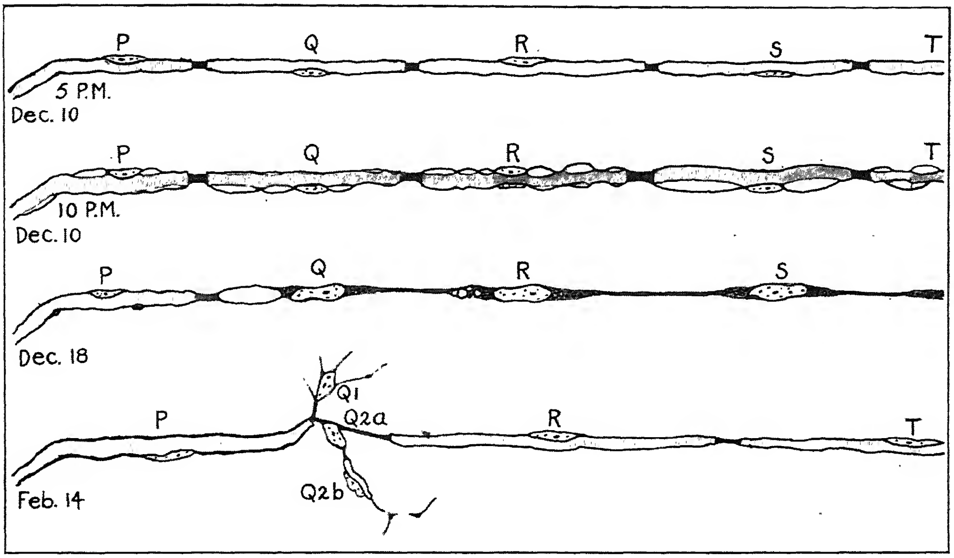


FIG. 3. DEGENERATION OF MYELIN SHEATH SEGMENTS AFTER A SINGLE SEVERE ALCOHOL TREATMENT.

ON DECEMBER 10 A LONG NORMAL MYELINATED NERVE FIBER WAS OBSERVED. FOUR OF THE MYELIN SEGMENTS (P, Q, R AND S) ARE SHOWN. BEYOND S IN THE DIRECTION OF THE END OF THE FIBER ARE 13 MORE SEGMENTS. TO THE LEFT OF P, 5 MORE SEGMENTS WERE VISIBLE. IMMERSION OF THE TADPOLE IN 2.5 PER CENT. ALCOHOL FOR 5 HOURS WAS SUFFICIENT TO STUN IT AND TO INITIATE THE BREAKING UP OF MYELIN SEGMENTS. SEGMENTS P, Q, R, S AND T ALL SHOWED MARKED SWELLING AND VACUOLE FORMATION, AS DID THOSE TO THE LEFT OF P (NOT FIGURED). SEVERAL SEGMENTS TOWARD THE END OF THE FIBER (NOT FIGURED) WERE BREAKING UP. ALL SEGMENTS FROM R TO THE END OF THE FIBER, 15 IN ALL, DEGENERATED; ALL SEGMENTS FROM P IN THE OPPOSITE DIRECTION (PROXIMALLY) RECOVERED. SEGMENT Q DEGENERATED PARTIALLY, BUT THE MYELIN TO THE LEFT JOINED THAT OF SEGMENT P. NEW SEGMENTS WERE FORMED ALONG THE FIBER, TEN IN ALL DEVELOPING TO REPLACE THE LOST ONES. SHEATH CELL Q DIVIDED, AND ONE OF THE DAUGHTER CELLS DIVIDED AGAIN, THREE CELLS THUS ARISING (Q_1, Q_{2a} AND Q_{2b}). NEW COLLATERAL SPROUTS APPEARED IN THE VICINITY. THESE SPROUTS GREW OUT AND ESTABLISHED CONNECTIONS WITH THE SKIN (NOT FIGURED). ON ONE OF THE FIBERS A SMALL NEW MYELIN SEGMENT WAS FORMED AT Q_{2b}.

amputation of a variable length of nerve fiber). Recovery of the endings after normal conditions are restored takes place readily. If the ending is merely swollen it becomes reduced in size. Usually several hours is ample time for such reduction to be effected. If retraction has taken place with a delicate filament left at the end, the neuroplasm flows forward and a growth cone is formed which advances and later becomes transformed into a knob-like ending. If autotomy has taken place, a growth cone may develop and advance along the former route (or a new route) to the skin. Essentially, these reactions are like those already described for growing nerve tips during active regeneration. They are not so conspicuous, however, and rather severe treatments are necessary to bring about the effects. If the treatment with alcohol is mild, the nerve endings exhibit little or no change.

In several cases by careful manipulation I have been able to observe the

autotomy refers to the similar procedure by which a nerve fiber pinches off its terminal portion.

changes in the same set of nerve endings during several successive periods of irritation and recovery. These experiments make it certain that the effects are directly ascribable to alcohol. Successive conditions of retraction and advance have been recorded in dozens of cases.

In the higher animals, all coordinated movements involve more than one nerve cell. Nervous impulses must be transmitted from cell to cell. The place of junction between two nerve cells is the synapse. Unfortunately, however, synapses are not in favorable positions for direct observation. I have not, therefore, succeeded in watching them in the living animal. Nevertheless, the changes in cutaneous nerve endings induced by

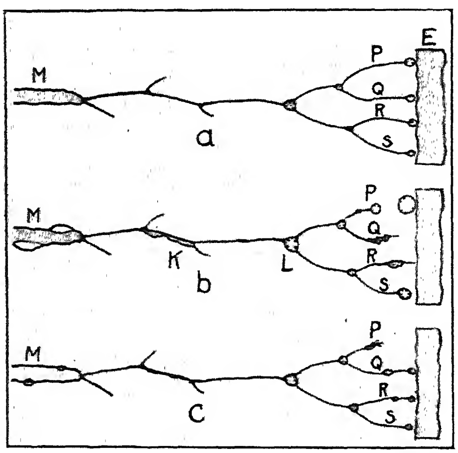


FIG. 5. CHANGES IN THE CUTANEOUS ENDINGS OF A NERVE FIBER DURING ALCOHOLIC INTOXICATION AND RECOVERY.

a, FROM THE TERMINAL MYELIN SEGMENT, M, A BRANCH EMERGES WHICH EXTENDS TO THE SKIN EPIDERMIS, E. FOUR OF THE END BRANCHES (P, Q, R AND S) ARE SHOWN, EACH TERMINATING IN A SMALL END BULB. *b*, AFTER 90 MINUTES OF TREATMENT WITH ALCOHOL (3 PER CENT.) IRRITATION BECOMES MARKED. THE ENDING P SWELLS AND IS CUT OFF. THE ENDING Q RETRACTS SLIGHTLY. THE ENDING R SHOWS RETRACTION OF THE END BULB. THE ENDING S SHOWS NO CHANGE EXCEPT SWELLING OF THE END BULB. *c*, A FEW HOURS LATER THE ENDINGS Q, R AND S HAVE RESUMED APPROXIMATELY THEIR FORMER POSITIONS. A GROWTH CONE HAS DEVELOPED ON P. LATER THIS WILL GROW TO THE SKIN, LOSE THE DELICATE BRUSH-LIKE PSEUDOPODS AND DEVELOP A ROUNDED END BULB.

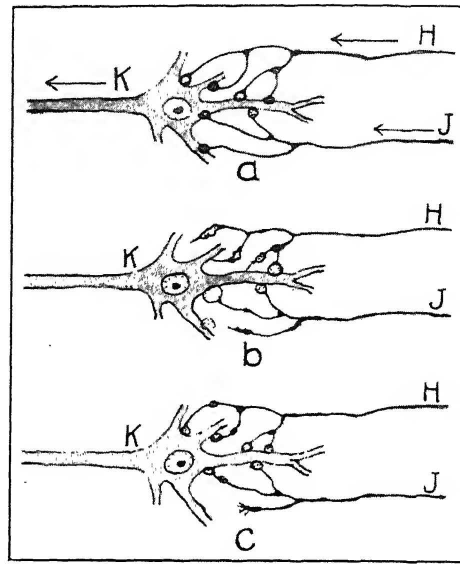


FIG. 6. DIAGRAM TO SHOW HOW THE NERVE ENDINGS AT A SYNAPSE BETWEEN TWO NERVE CELLS MAY BE MODIFIED DURING ALCOHOLIC INTOXICATION AND RECOVERY.

a, THE NERVE BRANCHES H AND J COME FROM NERVE CELLS LOCATED TO THE RIGHT, NOT SHOWN IN THE FIGURE. FIBER H ENDS IN 4 END BULBS ON THE NERVE CELL K; FIBER J ENDS IN 3 END BULBS. NERVOUS IMPULSES PASS ALONG H AND J IN THE DIRECTION INDICATED BY THE ARROWS AT THE RIGHT AND ARE TRANSMITTED ACROSS THE SYNAPSE (THE CONTACT ZONE BETWEEN THE END BULBS AND THE NERVE CELL K) AND THEN PASS ALONG THE AXONE OF K AS INDICATED BY THE ARROW TO THE LEFT. *b*, FOLLOWING TREATMENT WITH ALCOHOL THREE OF THE ENDINGS OF H SHOW DEFINITE RETRACTION OF THE END BULB, AND THE FOURTH SHOWS SWELLING. THE ENDINGS OF J EXHIBIT RESPECTIVELY MARKED SWELLING FOR THE MIDDLE BRANCH, AUTOTOMY OF THE TERMINAL BULB FOR THE BRANCH BELOW AND NO CHANGE FOR THE BRANCH ABOVE. *c*, SEVERAL HOURS AFTER NORMAL CONDITIONS ARE RESTORED THE END BULBS ARE AGAIN IN NORMAL CONTACT WITH CELL K AND THE SWOLLEN ONES ARE REDUCED TO THE USUAL SIZE. A GROWING TIP ON THE LOWEST BRANCH WHICH UNDERWENT AUTOTOMY WILL ADVANCE AND REESTABLISH CONTACT WITH NERVE CELL K.

alcohol afford strong presumptive evidence of what probably takes place at a synapse.

A common type of synapse is that shown in the sketch (Fig. 6, a). Typical nerve endings are shown as they terminate in small end bulbs on the processes and cell body of a nerve cell. During an alcohol treatment of proper strength, swelling and retraction would probably occur (Fig. 6, b). With restoration of normal conditions the endings might again assume approximately their former position (Fig. 6, c).

It is obvious that both swelling and slight retraction of nerve endings at the synapse would probably interfere with perfect transmission of impulses from one nerve cell to the next. Coordination would thus be impaired. If synapses are thus interfered with in the brain there would be trouble with balance, with proper focusing of the eyes, with speech and with the various mental activities.

Effects of alcohol on unmyelinated fibers: Unmyelinated fibers encased with a neurilemma and with sheath cells seem relatively unaffected by alcohol. Except for occasional vacuolation and slight swelling no special changes have been noted, even in tadpoles that at the same time exhibit marked effects in myelinated fibers, growing nerve tips and nerve endings.

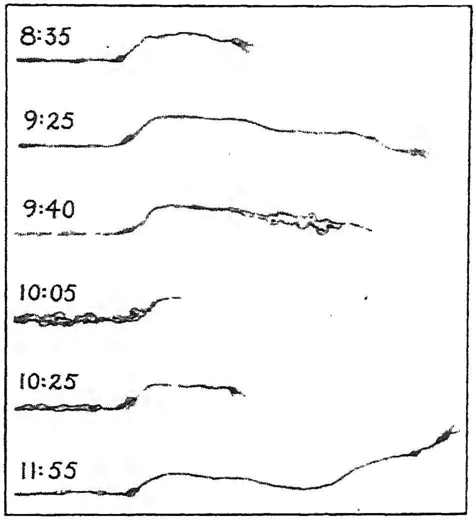
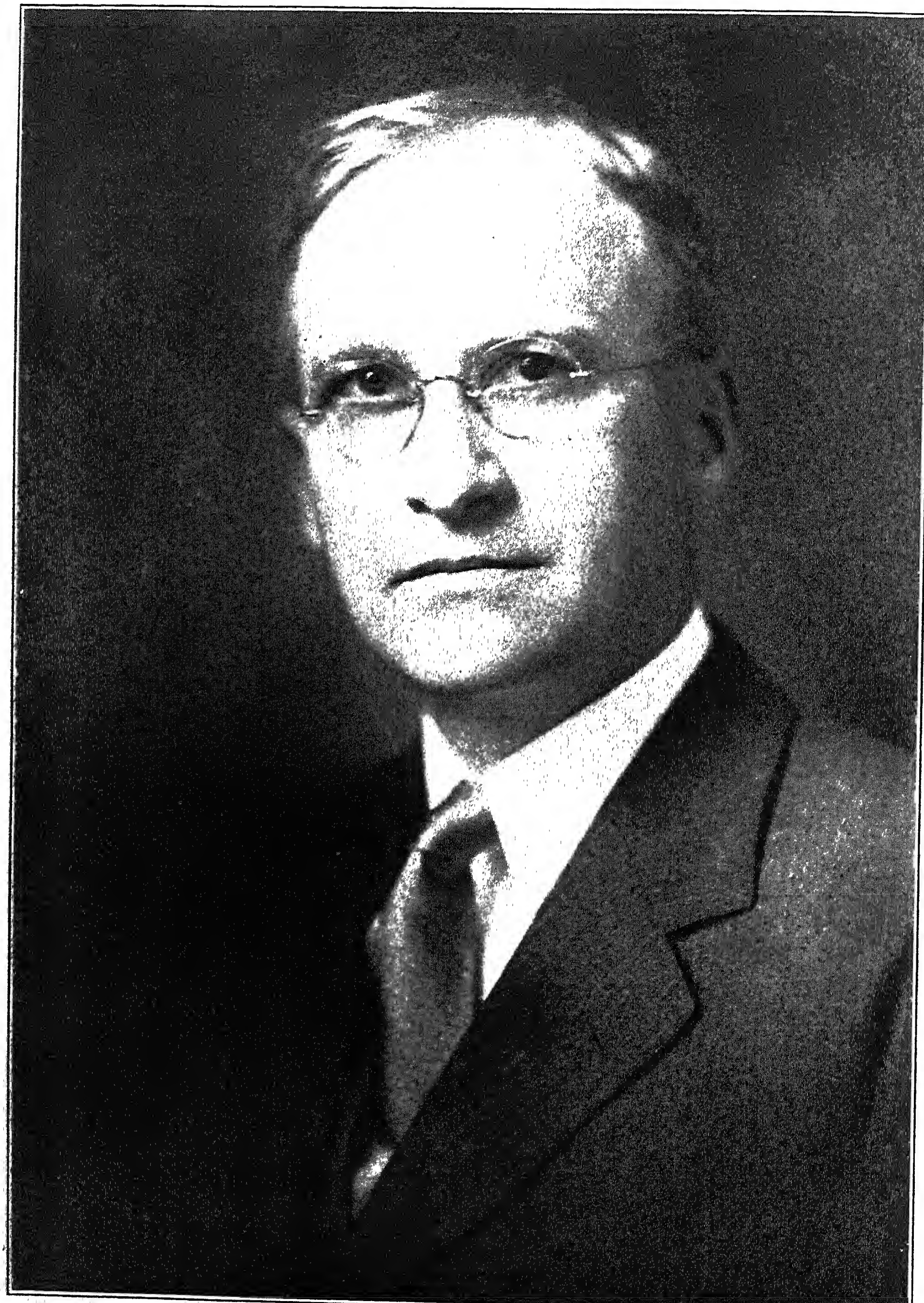


FIG. 4. CHANGES IN THE GROWING TIP OF A REGENERATING NERVE FIBER DURING ALCOHOLIC INTOXICATION AND RECOVERY.

8: 35–9: 25, A NERVE FIBER IN THE REGENERATING TAIL FIN OF A TADPOLE WAS OBSERVED FOR AN HOUR AS IT GREW RAPIDLY THROUGH THE TISSUES. AT 9: 25 THE TADPOLE WAS PLACED IN 2 PER CENT. ALCOHOL. AT 9: 40 DEFINITE RETRACTION WAS APPARENT, WHICH BECAME MORE PRONOUNCED DURING THE NEXT 25 MINUTES. AT 10: 05 THE ANIMAL IN SLIGHTLY DAZED CONDITION WAS REPLACED IN POND WATER. TEN MINUTES LATER THE FIRST SIGNS OF NEW GROWTH WERE VISIBLE AND 20 MINUTES LATER AT 10: 25 THE FIBER TIP WAS ACTIVELY ADVANCING. DURING THE NEXT 90 MINUTES GROWTH AGAIN TOOK PLACE NORMALLY, THOUGH THE FORMER ROUTE WAS NOT FOLLOWED EXACTLY. AT 11: 55 THE FIBER TIP HAD REACHED THE POSITION SHOWN.



DR. GEORGE D. BIRKHOFF

PERKINS PROFESSOR OF MATHEMATICS AND DEAN OF THE FACULTY OF ARTS AND SCIENCES AT HARVARD UNIVERSITY, PRESIDENT OF THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.

THE PROGRESS OF SCIENCE

THE ATLANTIC CITY MEETING OF THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE

ATLANTIC CITY is unique. In the first place, it is superbly located on a magnificent beach. In the second place, it is admirably adapted for taking care of large conventions. So the association's second Atlantic City meeting, held from December 28 to January 2, was as delightful and as successful as the first one, four years ago.

The attendance at this second meeting was about 4,000. The program included approximately 1,500 addresses and papers. Considerably more than half of these were on biological subjects, and of the remainder nearly one third dealt with agriculture. The physical and medical programs were extensive, and included important contributions.

The programs of the association's meetings reach a far larger audience than the one present when the papers are read. For they are reported by the leading science writers of the country and through them reach all the larger newspapers in the country and also many of those abroad. Through the work of these science writers the people as a whole as well as the members of the association can keep themselves informed regarding the progressive advance of science.

For the information of the members a special lecture was given on science and the American press by Mr. David Dietz, science editor of the Scripps-Howard Newspapers and formerly president of the National Association of Science Writers, which was supplemented by a talk on the history of science and the press by Mr. Watson Davis, director of Science Service. Both Mr. Dietz and Mr. Davis have reported the meetings of the association since 1921.

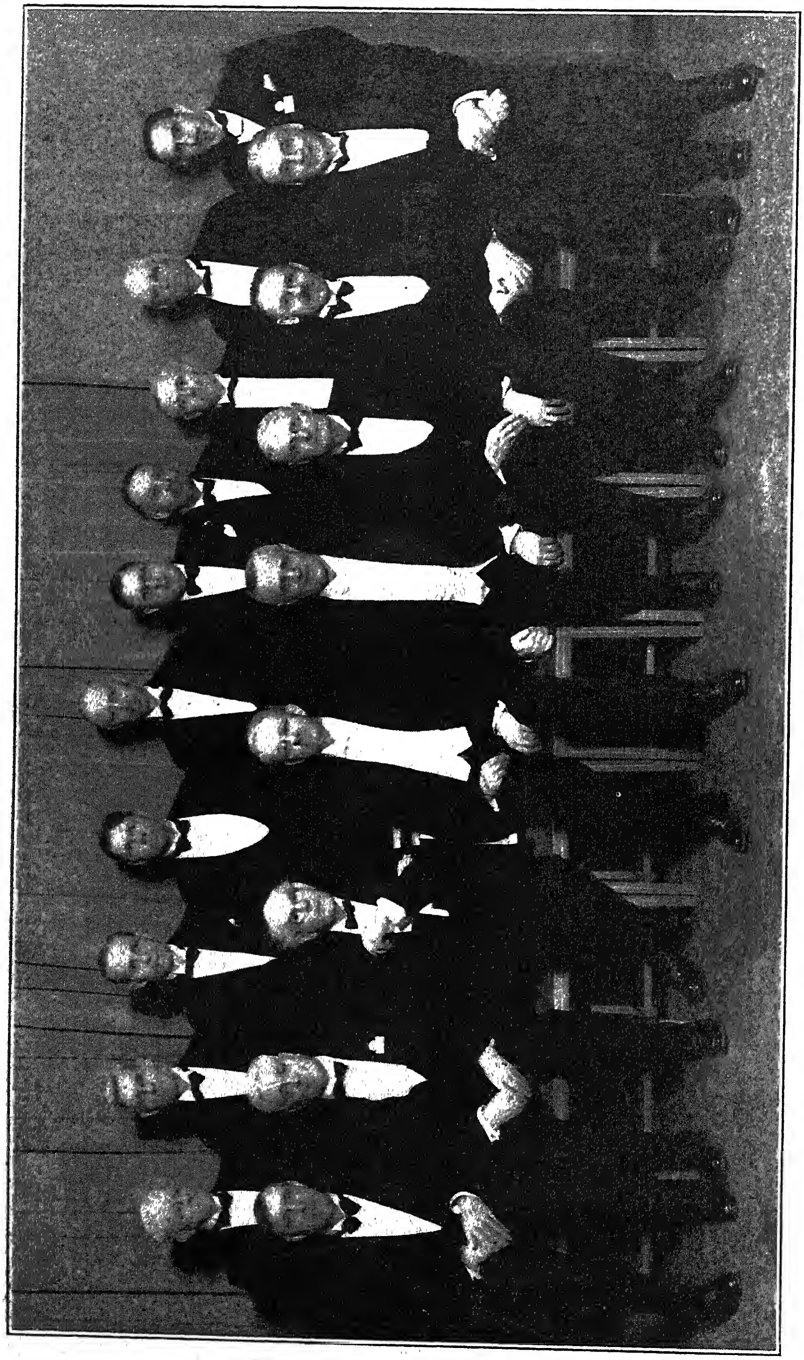
A novelty in this year's program was the setting aside of Friday, January 1, as "Association Day," with special programs arranged for afternoon and evening. Friday morning was mainly devoted to committee and board meetings for the discussion of matters of particular interest to science. Perhaps the most important of these were the meeting of the executive committee of the American Society for the Control of Cancer and the annual Secretaries' Conference.

In addition to these conferences the Ecological Society arranged a field trip to the Cape May peninsula, famous for the apparent anomalies of its fauna and flora, the Oyster Experiment Station and the Witmer Stone Wild Life Sanctuary. The only scheduled meeting was a symposium on New Jersey ferns under the auspices of the American Fern Society.

In the afternoon there were shown a number of unusual moving pictures of exceptional interest, presented by Dr. William Beebe, Perry Burgess, Professor E. M. K. Geiling, Dr. C. E. Turner and Dr. Harold E. Edgerton. Later, Dr. Walter Schiller, of the University of Vienna, gave an address on "Changes and Modifications in the Conception of Carcinoma."

In the evening there was a special private showing of "The Human Adventure," an eight-reel talking picture sketching man's rise from savagery to civilization, produced under the direct scientific supervision of the late Dr. James Henry Breasted by the Oriental Institute of the University of Chicago. The second reel was accompanied by a sound record in the voice of Dr. Breasted.

The association was invited to hold the sessions on Saturday in Philadelphia under the auspices of the American Philosophical Society, one of the oldest, most widely known and most influential of American scientific organizations. This invitation, needless to say, met with an enthusiastic reception. Saturday morning was devoted to a most interest-



OFFICERS OF THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE

THE PRESIDENT, THE RETIRING PRESIDENT, VICE-PRESIDENTS AND MEMBERS OF THE EXECUTIVE COMMITTEE, ON THE OCCASION OF THE DELIVERY OF THE ADDRESS OF THE RETIRING PRESIDENT, DR. KARL T. COMPTON, PRESIDENT OF THE MASSACHUSETTS INSTITUTE OF TECHNOLOGY. DR. E. G. CONKLIN, EMERITUS PROFESSOR OF BIOLOGY, PRINCETON UNIVERSITY, AND DR. COMPTON ARE SEATED IN THE CENTER. ON THE LATTER'S LEFT IS DR. HENRY B. WARD, PERMANENT SECRETARY OF THE ASSOCIATION.

Pictures, Inc.

DR. C. G. ABBOT, SECRETARY OF THE SMITHSONIAN INSTITUTION, DEMONSTRATING HIS SOLAR ENGINE. FOUR 250-WATT ELECTRIC LIGHTS WERE USED AS A SUBSTITUTE FOR THE SUN AT THE EXHIBITION.

ing program of five papers on viruses and virus diseases. In the afternoon the historic Academy of Natural Sciences and the Franklin Institute were visited. The meetings closed with a most enjoyable tea served at the Franklin Institute.

In connection with the association's program there has been given at each winter meeting for the past thirteen years a prize of $1,000 to the author of a noteworthy paper. The awarding of this prize is made possible through the generosity of a member who prefers to remain anonymous. The recipient of this prize this year was Dr. Wendell Meredith Stanley, of the Rockefeller Institute for Medical Research, at Princeton, New Jersey. His paper was entitled "Chemical Studies on the Virus of Tobacco Mosaic." It is expected that Dr. Stanley will give a more detailed account of his researches at the next winter meeting at Indianapolis.

The exhibitions this year were, as usual, varied, interesting and instructive. Indeed, the entire week could profitably have been spent in studying them. Governmental agencies, both federal and state, universities, commercial firms and individuals combined to assemble a well-rounded science museum. Official participants included the Meteorological Service of Canada, the Smithsonian Institution, the National Bureau of Standards, the Bureau of Chemistry and Soils, the Weather Bureau, the Bureau of Mines, the Federal Bureau of Investigation, the Rural Electrification Administration, the Commonwealth of Virginia, and the Agricultural Experiment Stations of Utah and Nevada. Harvard University and the Massachusetts Institute of Technology joined with the Meteorological Service of Canada, the National Bureau of Standards, the Weather Bureau and leading manufacturers in a display of aerological apparatus.

The exhibits sponsored by the American Society for the Control of Cancer and the National Tuberculosis Association were most instructive to those who had not followed the work of these or-

ganizations. The astronomical exhibit showing the work of our American observatories was fascinating, as was that of the cosmic ray apparatus and the charts showing some of the results of recent surveys of the intensity of these rays. The latest and most efficient type of solar engine proved to be of interest to many.

The display of the most recent types of scientific instruments was very instructive. To those among us who remember the physical, chemical and biological laboratories of thirty years ago it was, as usual, a revelation.

As a part of the exhibit the Science Library has become a regular feature, giving just as true a picture of the year's progress in science as do the displays and demonstrations. This year there were shown 523 books, representing practically the complete production for 1936. The association is much indebted to the cooperation of the publishers and others who have made possible this important feature of the annual exhibit.

In addition to the main exhibit in the Municipal Auditorium there were various other exhibits and demonstrations, chiefly of a more or less specialized nature. Of these the one that attracted the largest number of students in other lines, and of laymen, was the diversified display shown by the Entomological Society of America in Haddon Hall.

No meeting of this kind could be successful without the most efficient sort of local cooperation. Efficiency and Atlantic City seem synonymous in so far as the handling of large conventions is concerned. We learned that at the time of our first meeting there in 1932, and our impressions of that time have been confirmed by our recent visit. We are under great obligations to Mr. A. H. Skean,

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DR. G. E. HULL OF DARTMOUTH COLLEGE

EXAMINING THE CELLULOID MODEL OF THE 200-INCH TELESCOPE.

Pictures, Inc.

DR. IRVING LANGMUIR OF THE GENERAL ELECTRIC COMPANY

DEMONSTRATING HIS BUILT-UP FILMS OF PROTEINS AT THE SCIENCE EXHIBITION.

director of the Convention Bureau of Atlantic City, for his interest in science and in our meeting, and for the splendidly cooperative spirit that he showed on all occasions.

AUSTIN H. CLARK

PROFESSOR GEORGE D. BIRKHOFF, PRESIDENT OF THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE

THE new president of the American Association for the Advancement of Science, though in appearance a young man, has to his credit actually thirty years of college teaching. Not all on one campus, however, but longest at Harvard University. His educational career has been diversified. Born at Overisel in Michigan on the vernal equinox in 1884, he was graduated from Harvard at twenty-one, and one year later received the A.M. degree. Now began, we may say, his purposeful progress, for he knew what he could do and chose his steps independently. Already he was looked upon as a scholar, for in his junior year he had read an important paper before the American Mathematical Society. This, with extensive additions, he published soon after graduation in Volume 7 of the society's *Transactions*. Studying at the University of Chicago, chiefly under the stimulating influence of the late E. H. Moore, he reached the doctorate in 1907. For the next two years he taught in the University of Wisconsin under the presidency of Van Hise, with such colleagues as Van Vleck, Slichter and Max Mason. Next he is seen at Princeton, at first as a preceptor, where

Dean Fine was assembling the departmental staff whose growth has been so phenomenal. Here his associates included Eisenhart, Thompson, Veblen, Wedderburn, MacNeish. But he had special ends in view, and in 1912 resigned a full professorship to accept an assistant professor's status at Harvard. No doubt early ties were strong, but in particular the close cooperation of Maxime Bocher would be most helpful at that stage in his study of differential equations. There he has remained, in spite of temptations, and advanced to full professorship and quite recently to the rank of research professor and dean of the Faculty of Arts and Sciences. Harvard, Chicago, Madison, Princeton, a summer in California, and back to Cambridge—an instructive range of experience.

These were not merely stations, but centers of mathematical intercourse, and Birkhoff's nature is intensely social. Meantime his field of research and publication has extended. Differential equations, singly and in systems, and particularly those of dynamics and electricity, occupied ten years or more; and he became one of the earliest students and a leading exponent of relativity in this country. His Lowell Lectures (1923) and a later series at the University of California (Los Angeles) were condensed into a little book which is full of clear exposition and criticism of relativity and competing philosophical systems, and is by no means out of date after twelve years—"The Origin, Nature and Influence of Relativity." Reading this, one remembers that Birkhoff's years at Harvard brought contacts with Royce, James, Bergson and Whitehead, reinforcing evidently a native tendency to profound speculation.

A book often gives some measure of the man. Synopsis is impossible, for it is itself a synopsis, but two extracts may give some impression of its nature. First, a cryptic summary: "The meaning of the nature-mind spectrum is a matter of interest. If we are objectivistic in tendency, we call it the Absolute; if subjectivistic, knowledge."

The second, showing the truly catholic attitude of the writer—a confirmed relativist but no fanatic: "The usefulness of an abstraction is relative to its inherent simplicity of structure and its agreement with the facts. The example, the usefulness of the theory of relativity depends on the circumstance that it possesses the same inherent simplicity as the classical theory, while it explains more facts than that theory did."

Not all Birkhoff's philosophizing is so technical. A distinguished preacher told me that much of the obscurity of professional logicians had been cleared up for him by long walks and talks with Birkhoff. Possibly it was this quality of lucidity that won for him the prize of the A.A.A.S. in 1926; it explains much of his popularity as a lecturer.

As a frequent contributor to the *Transactions* of the American Mathematical Society, Birkhoff has done much toward establishing the reputation of that journal at home and abroad. I may mention a short paper in 1913 that attracted immediate attention. Poincaré had enunciated what seemed a beautifully simple theorem on geometric transformations of a plane ring bounded by two circles, but had for years sought in vain for a proof. It bade fair to become as celebrated as Fermat's "Last Theorem." When it came to Birkhoff's notice, however, he saw at once that methods of attack which he had used for several years on other problems would resolve this difficulty, and gave the complete proof in 1913. Not long after, in 1918, the *Transactions* printed his long and elaborate treatment of "Dynamical Systems with Two Degrees of Freedom." This systematized fragmentary theories and reduced the general problem to a finite number of typical or "normal" forms. For this essay he was honored by the society with the first award (1923) of its Bocher prize.

This recognition came five years after the occasion. Meantime, in 1918, the author had been honored by election, at the early age of 34, to the National Academy of Sciences. This early inclusion in that small body of research scientists is rarely achieved; other instances are Newcomb, A. A. Michelson, Theodore W. Richards and George E. Hale. Other honors that have come to him are honorary membership in the Göttingen Scientific Society, the French Academy of Sciences, the Royal Danish Society of Sciences and Letters, the Royal Academy of Lincei and the Academy of Sciences at Bologna. He is one of the few non-Italian fellows of the new Pontifical Academy of Science. Of special prizes, he has received from Venice the Quirini-Stampolia prize, and a Pontifical Academy prize for researches on systems of differential equations. He has just been made an officer of the French Legion of Honor. Honorary degrees have been awarded to him by Brown, Wisconsin and Harvard Universities, and the Universities of Paris and of Poitiers.

As the office of dean marks a growth in educational influence beyond the bounds of a single department, so, his friends believe, does the appearance of his most recent book, not on pure mathematics, entitled "Aesthetic Measure." The next few years will develop its value; as also that of his latest contribution at the recent winter meeting of the A.A.A.S., to the mathematical theory of electricity and gravitation.

Birkhoff's ancestry is from Holland. His physique, tall and lithe, over six feet, with broad shoulders and well-set head, is less slender than that of the boy whose individuality and originality first attracted the notice of the Mathematical Society. It is worth noting that a son, Garrett, shows distinct ability and promise in abstruse mathematics.

This brief sketch may explain in part the election of another modest mathematician to the chair sometime occupied by Chauvenet, Lovering, H. A. Newton, Simon Newcomb and E. H. Moore.

Henry S. White

AWARD OF THE AMERICAN ASSOCIATION PRIZE TO DR. STANLEY

For his paper presenting strong evidence that the virus which causes the infectious mosaic disease of tobacco plants is a non-living crystalline protein, Dr. Wendell Meredith Stanley received the thousand-dollar prize of the American Association for the Advancement of Science. Dr. Stanley gave his paper before the joint session of Section G (Botanical Sciences) with associated societies at Atlantic City on the afternoon of December 29; his work was also presented at a symposium on virus diseases held in Philadelphia on January 2 under the auspices of the association and the American Philosophical Society.

Dr. Stanley's research, indicating that the viruses are giant protein molecules and not invisible living organisms, provides a new scientific approach to the study of all virus diseases—including influenza, infantile paralysis, encephalitis, measles, smallpox, yellow fever and the common cold, as well as many other diseases affecting man, animals and plants.

The first disease-producing virus was discovered forty-five years ago when it was found that the juice from diseased tobacco plants retained its infectious property after passing through a bacterium-proof Chamberland filter. Discovery of a score of other viruses followed rapidly, and they were recognized, along with bacteria, protozoa and fungi, as infectious pathogenic agents. The virus, though capable of increasing indefinitely within susceptible hosts, could not be cultured apart from living cells, nor was it visible under the highest power of the microscope. Pathologists could only speculate as to its nature. One theory held the virus to be a sub-microscopic bacterium-like organism; another considered it a contagious living fluid; a third

regarded it as some kind of inanimate chemical substance. But all efforts to isolate the infectious principle in pure form were futile until Dr. Stanley in 1935 succeeded in obtaining a crystalline protein that possessed the properties of the virus. A series of brilliant investigations have since yielded convincing evidence supporting the view that the protein actually is identical with the virus.

Dr. Stanley was born at Ridgeville, Indiana, on August 16, 1904. He was graduated with the degree of B.S. from Earlham College in 1926. As a graduate student at the University of Illinois he worked in organic chemistry, and took minors in physical chemistry and bacteriology. He received the Ph.D. degree in 1929, and in the same year he married Miss Marian Staples Jay, then a graduate student in chemistry and mathematics. Following work at the University of Illinois as research associate and instructor, he went in 1930 to the University of Munich for a year as international research fellow in chemistry. He was appointed to the staff of the Rockefeller Institute for Medical Research in 1931, and in the following year he joined the newly assembled group of research workers, headed by Dr. L. O. Kunkel, who were investigating fundamental problems of plant pathology at the Princeton laboratories of the institute.

Dr. Stanley has published thirty-eight scientific contributions. His investigations cross the borders of botany, chemistry, physics, zoology, bacteriology and medicine, and include research on organic compounds with bactericidal action toward *Mycobacterium leprae*, the sterochemistry of diphenyl compounds, the isolation of yeast sterols and the preparation of a model that simulates the alga Valonia in trapping potassium. In the Department of Animal and Plant Pathology of the Rockefeller Institute, he has carried on chemical studies of the virus of tobacco mosaic. This work has culminated in the discoveries which were reported in his prize-winning paper. Among significant points brought out by Dr. Stanley are the following:

The pathogenic activity of the crystalline virus protein is 500 times as great as that of the crude juice. Twenty drops of a solution containing 1 pound of the protein in 120 million gallons of water would usually prove infectious, and under the most favorable conditions a solution one-hundred-thousandth as strong (with only 15 molecules per drop) would suffice. Since only a small part of the solution applied to the leaf actually comes in contact with susceptible cells, a very few molecules—or possibly only one molecule—may be capable of producing the disease. Following inoculation the virus protein increases until it makes up about 85 per cent. of all the protein in the diseased tobacco plant.

An unexpected finding was the enormous size of the virus protein molecule, with a weight (as determined by Dr. Svedberg and Dr. Wyckoff) 17,000,000 times that of the hydrogen atom. No other known protein approaches this magnitude.

A series of tests have demonstrated the uniformity and purity of the virus protein. The disease-producing activity, chemical composition, isoelectric point (pH 3.3), molecular weight, x-ray diffraction pattern and optical rotation of the protein obtained from many samples of plant juice were the same. These properties remained constant on recrystallization, on fractional crystallization or on fractionation by adsorption methods.

Assuming the molecule to be spherical, the molecular weight of 17,000,000 corresponds to a protein molecule about 35 millimicrons in diameter—about one fourteenth the diameter of the smallest bacteria. Although the dissolved protein passes a Berkefeld W filter, it is held back by collodion filters through which the smaller molecules of egg albumin can pass. The virus activity can not be separated from the protein by filtration.

The serological properties, as shown by

the precipitin test, were found to be the same for the protein as for the juice from diseased plants. It is significant also that by suitable chemical treatments the virus could be inactivated without destroying its immunological properties.

Different kinds of plants are susceptible to the tobacco-mosaic disease. Dr. Stanley succeeded in isolating the same high-molecular-weight crystallizable protein from diseased Turkish and Burley tobacco and tomato plants—also from such unrelated plants as spinach and phlox; but he has never been able to find this protein in healthy plants.

An interesting suggestion is that the tobacco-mosaic virus may undergo mutation or evolution. Thus four different strains of the virus—including the ordinary, a single-lesion, a yellow and a masked strain—are characterized by four different, though closely related, crystallizable high-molecular-weight proteins.

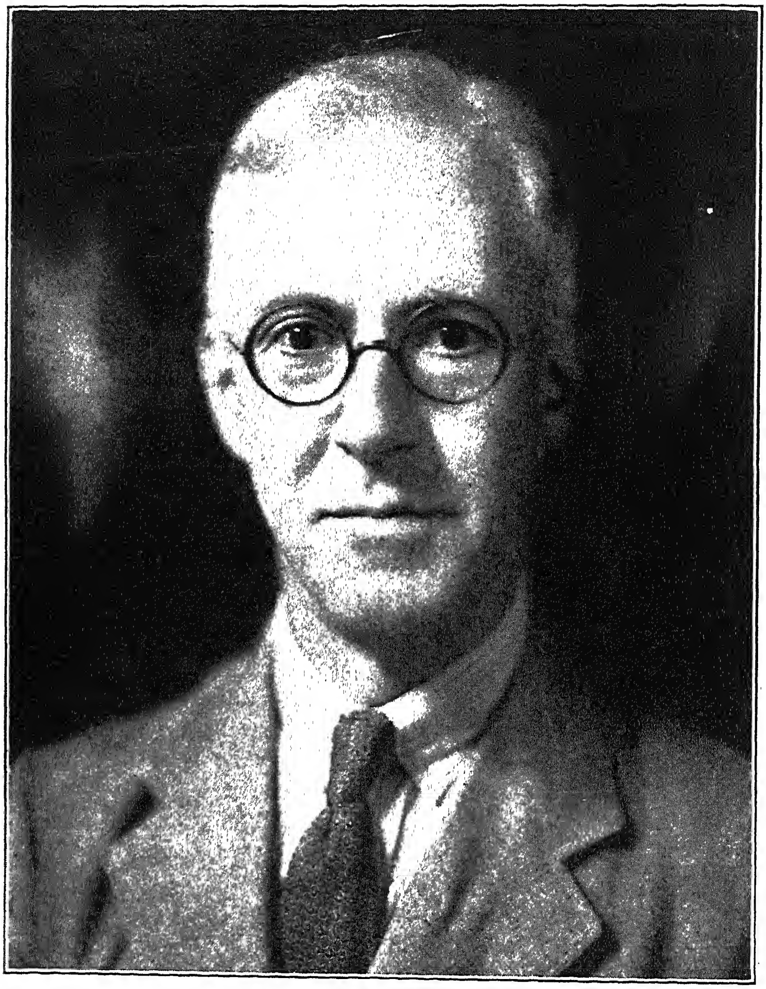
Dr. Stanley has not overlooked the possibility that the crystalline protein which he has isolated may consist chiefly of inert protein plus an amount of active virus agent so small as to escape detection. But in view of the great dilution which the protein will stand and still remain active, it seems highly improbable that the presence of a few tenths of one per cent. of impurity which it may contain could account for the virus activity. Special technique was employed to determine whether the virus activity might be due to an impurity adsorbed on the surface of the protein. The method consisted in the removal of the protein selectively from solution by centrifugal force under conditions that would release any impurity adsorbed on the protein. It has been impossible to separate the virus activity from the protein, but the evidence points to the conclusion that the protein itself is actually the virus.

Although the protein molecule is non-living, it possesses some properties, such as specificity of host range and ability to reproduce and mutate, which are generally regarded as characteristic of living things. The enormous size of this molecule may enable it to possess sufficient organization to endow it with such properties. It is interesting to speculate on some of the implications of the observed facts. Possibly the borderline between the living and the non-living tends to become non-existent in these huge molecules. They may represent a link between the type of organization within the inanimate molecule and the kind of organization within the living cell. In any event, it now appears possible to list protein molecules along with living organisms as infectious disease-producing agents. Infection involves the introduction of a few molecules of a virus protein into a susceptible host. These few molecules appear to have the ability to direct the metabolism of the host so that it produces, not normal protein, but more of the virus protein. Dr. Stanley says that whether one regards this protein as living, as non-living, as a gene, as a supercatalyst, as an organizer or as a pathological protein, its study is most fascinating.

SAM F. TRELEASE,
Secretary of the Section of Botanical Sciences

THE NOBEL PRIZE IN PHYSIOLOGY AND MEDICINE

THE award of the Nobel Prize in physiology and medicine for 1936 to Sir Henry H. Dale of London and Professor Otto Loewi of Graz, because of their investigations of the rôle of acetylcholine as a chemical mediator of nerve impulses, will be recognized widely as well warranted. Admittedly, suggestions that a chemical step intervenes between the nerve impulse and the muscular response had been offered before they began their experiments. In 1904 T. R. Elliott had put forward the bold idea that the reason why the secretion of the adrenal glands, adrenine, duplicates generally throughout the organism the effect of



SIR HENRY H. DALE

sympathetic impulses might be found in the possibility that these impulses normally release adrenine locally on their arrival at the muscle and that this local product acts in all ways like adrenine secreted from the adrenal medulla. Later Dixon had generalized this view. But no experimental proof for it was found.

In 1906 Reid Hunt and Taveau called attention to the remarkable potency of extremely minute quantities of acetylcholine in producing changes in the organism. And shortly before the war Dale discovered the interesting fact that, much as adrenine mimics the action of sympathetic nerve impulses, acetylcholine mimics the action of parasympathetic impulses. The next step was taken when in 1921 Loewi published his impressive and highly significant experiments. They were made in a remarkably simple and direct manner. He prepared two frog hearts, A and B. In the chamber of heart A was introduced normal salt solution. Now the vagus nerves supplied to this heart were stimulated so that the heart was checked in its action or inhibited. After this influence had been exerted for some time Loewi removed the salt solution from heart A and intro-

PROFESSOR OTTO LOEWI

duced it into heart B, which was beating. Thereupon the active heart B was inhibited, much as heart A had been inhibited. The inference was drawn that the vagus impulses on reaching heart A caused the appearance of a chemical substance which not only stopped that heart but which, produced in excess, entered the solution in the cardiac chamber, and, when transferred to the chamber of heart B, had there the same effect as the vagus impulses themselves.

Later studies by Loewi and his assistants brought forth evidence that "vagus substance" is in fact acetylcholine, the material which Dale had proved to be capable of reproducing generally the effects of parasympathetic nerve impulses. Further researches soon demonstrated that other nerves belonging to the parasympathetic category are capable of discharging into perfusates, passed through organs stimulated via parasympathetic fibers, an acetylcholine-like substance, capable of lowering blood pressure, inhibiting the heart, and causing other characteristic alterations.

Investigations conducted by Dale and his collaborators extended the work which he had undertaken in 1914. First,

by finding acetylcholine in the spleen and the human placenta, it was proved to be a natural constituent of the body. Furthermore, evidence accumulated that the curious Vulpian phenomenon—a mysterious slow contraction of denervated voluntary muscles which occurs when autonomic impulses relax the blood vessels of these muscles—could be explained by a diffusion of acetylcholine from the smooth muscles of the vessels to the sensitized striped muscles. Dale also explained an anomaly which has long spoiled the generalization that adrenine mimics sympathetic impulses. As stated above, it is the rule that adrenine does reproduce the effects of these impulses. In man and the cat, however, sweat glands break the rule—pilocarpine, for example. By careful experiments it was shown that the *sympathetic* supply to sweat glands induces a discharge of acetylcholine. On the basis of this observation Dale suggested a more exact classification of autonomic nerves than the division into sympathetic and parasympathetic groups, *i.e.*, a classification into those which produce an adrenine-like substance, adrenergic fibers, and those which produce acetylcholine, the cholinergic.

The most recent and most interesting developments which have come from Dale's group have resulted from extension of the idea of chemical mediation of nerve impulses. A chemical phase appears not only when the impulses arrive at glands and smooth muscle but also when they pass from neuron to neuron in sympathetic ganglia, and from motoneuron to skeletal muscle. Kibjakow, a young Russian, had obtained, in 1932, evidence that a mimetic substance is produced in the superior cervical ganglion by incoming impulses. A perfusate taken during stimulation caused, in Kibjakow's experiments, the same effect as the impulses themselves when it was reperfused through the ganglion. In Dale's laboratory this observation was not confirmed, but clear evidence was obtained that, in fact, when nerves deliver impulses to a sympathetic ganglion, there is produced in the ganglion an appreciable amount of acetylcholine; and that acetylcholine applied to the ganglion has effects similar to those produced by the impulses themselves.

Many years ago T. R. Elliott called attention to the resemblance between the pharmacological evidence of conditions at connections of neurons in ganglia and at connections of nerve fibers with skeletal muscle cells. Last summer an important paper was published by Brown, Dale and Feldberg, announcing that acetylcholine, when introduced directly into the arteries supplying a muscle, produces a strong twitch-like contraction of the muscle. This phenomenon is related to previous evidence which had been obtained by Dale that pure motor impulses, delivered to the muscles of the tongue, liberate acetylcholine. The case becomes, therefore, fairly strong that not only is acetylcholine a mediator of parasympathetic and of some sympathetic impulses—distributed to the heart, the stomach, the intestines, the bladder and salivary and sweat glands—but also that it is an intermediary at the junctions of neurons in ganglia and at the myriads of endings of motoneurons in voluntary muscles.

Obviously a new realm in physiology is disclosed by these important researches, and it will be well to watch for further advances in the attractive realm in which Dale and Loewi have pioneered.

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THE SCIENTIFIC MONTHLY

MARCH, 1937

THE EARTH'S INTERIOR, ITS NATURE AND COMPOSITION

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Two events in the last few years have made possible a noteworthy advance in our knowledge of the earth's interior, and have for the first time extended our ideas on this subject definitely beyond those of the early Greek philosophers. The two aids to progress were, first, the precise measurement of the elastic properties of rocks and, second, an improved technique in seismology which permitted the accumulation of reliable data on the speeds of waves from near and from distant earthquakes. Other researches in geophysics have played an important, although secondary rôle, and have promoted a steady improvement in our knowledge of the earth as a whole. It is the object of this communication to summarize briefly the present notions concerning the earth's interior and the steps by which the information has been obtained.

ORIGIN OF THE EARTH

A discussion of the interior of the earth should properly start with a consideration of its origin and its place in the universe. Geophysics begins with cosmogony. Our earth is a spherical body about 8,000 miles in diameter floating in nearly empty space. Its nearest neighbor, the moon, is a quarter of a million miles away. Together, they revolve around the sun at a distance of some 90 million miles. The other planets of the solar system circle around the same sun, which, although by far the largest object in the system, is merely a star like countless others that dot the sky, and is, as stars go, a rather small and insignificant one. Separated from the sun by enormous distances are the other stars of our galaxy, which has a disk-like form and an extent of at least 50,000 light years, and is merely one of the innumerable spiral nebulae scattered irregularly through space at an average distance of perhaps 1,000,000 light years.

On so vast a scale, our earth, a tiny planet accompanying a small star, seems to dwindle into insignificance, but it is after all the place where we dwell and have our being, and for us it has the importance attaching to a great object, which, except for the surface layers, is as yet unexplored.

It is now generally accepted that the earth was created from the parent sun about 2,000 million years ago through tidal disruption by a passing star. The subsequent liquefaction and solidification of the detached mass of glowing gas formed the juvenile earth. This notion, advanced by Jeans and Jeffreys, is quite different from that involved in the nebular hypothesis of Laplace, according to which the sun was originally surrounded by a rarefied nebula which rotated about

the central mass. As the nebular material cooled it was supposed to contract and increase its speed of rotation, until finally the centrifugal force was sufficient to detach a ring of material, which condensed to form a planet. Although accepted for many years, the hypothesis was finally discarded on purely mathematical grounds. The theory now in favor also differs in many important details from another tidal theory, the planetesimal hypothesis enunciated by Chamberlin and Moulton. This was the first to account satisfactorily for many of the major features of the solar system, and involved the formation, from the tidal protuberances, of swarms of solid fragments (planetesimals), which coalesced around various nuclei and thus produced the planets. The significance of the modern theory, for the purposes of this discussion, lies in the supposition that *the earth for a brief time after its creation was entirely molten,* well stirred by convection, and, to the extent that the component substances were miscible in the liquid state, quite homogeneous in composition.

Nature of the Problem

The composition and state of the earth's interior has long remained a problem of great difficulty. It is at the same time a subject of lasting interest, alike for the scientist and for the layman. There is always a certain fascination in the mysterious and unknown, especially when it appears impossible to solve the problems that are presented. If it should seem a hopeless task to learn anything about the interior of the earth, we might profit by adopting that philosophical attitude toward the origin of the earth and the nature of its interior which was expressed by Barrell[1] as follows:

> The history of the earth is read in the rocks which have been thrust up by internal forces and beveled across by erosion. The nearer events are clearly recorded in the sequence and nature of the sedimentary rocks and their fossils. But the oldest formations have been folded, mashed, and crystallized out of all resemblance to their original nature, and intruded by molten masses now solidified into granite and other igneous rocks. Fossils, the time markers of geology, if once existent, have been destroyed, and, as in the dawn of human history, vast periods of time are dimly sensed through the disordered and illegible record. This crystallized and intricately distorted series of the oldest terrestrial rocks tells of an earth surface on which air and water played their parts much as now. But it was a surface repeatedly overwhelmed by outpourings of basaltic lava on a vaster scale than those of later ages, and the crust was recurrently broken up and engulfed in the floods of rising granitic magmas. Here the geologic record begins, but the nature of its beginning points clearly to the existence of a prehistoric eon. At the farther bounds of this unrecorded time, forever hidden from direct observation, lies the origin of the earth.
>
> But the mind of man will not be baffled. Since he may not see directly he will see by inference. Convergent lines of evidence derived from various fields of knowledge may be followed part way toward this goal, like those rays perceived through the telescope on the full moon near the margin of its visible hemisphere, which converge toward craters on the side of the moon that no eye shall ever see.

Developments in various branches of science during recent years have enabled us to draw a picture showing, as yet none too clearly, what the interior is like. Any progress that may have been made is due to the joint effort of many investigators, in the laboratory and in the field. The measurements and observations have been interpreted through the medium of physics, of chemistry and of mathematics. The important part played by these exact sciences in the study of the earth was recognized many years ago. For example, the Advisory Committee on Geophysics of the Carnegie Institution of Washington in 1902 stated in its report: "The phenomena presented by the earth are the historical products of chemical and physical forces."

[1] Joseph Barrell, Chapter I in "The Evolution of the Earth." R. S. Lull and others. New Haven, 1919.

Sources of Information

We now proceed to discuss briefly the various sources of information concerning the earth's interior and to list the more important bits of evidence, which may be joined together to give us a notion of the constitution of the earth as a whole.

The surface of the earth has been thoroughly explored, and what lies just below the surface of the land masses has been carefully and patiently studied by geologists for many years. Thanks to the dissection of the surface by erosion, notably in deep canyons, we are able to learn much about the materials down to a depth of several thousand feet, so that we now have an accurate picture of the rock masses that lie below the superficial layer of soil and sedimentary rocks. Underneath this thin veneer there is mainly igneous rock, that is, rock that has solidified from molten magma. According to Clarke's estimate, the outer 10 miles of the earth consist of 95.0 per cent. igneous rock, 4.0 per cent. shale, 0.75 per cent. sandstone and 0.25 per cent. limestone. The labors of the geologist have given us a store of information concerning the structure and mineral composition of rocks and the interrelations of the various formations. Although there are an overwhelming number of rock types, with respect to composition and texture, curiously enough a predominating amount of the visible igneous rock is either granitic or basaltic. The land surfaces occupy only about one fourth of the area of the globe. Unfortunately little as yet is known about the rocks of the remaining three fourths, although something may be inferred from the geology of the ocean bottom by observations on oceanic islands. Direct sampling of the ocean floor has been limited to a few inches in depth until quite recently, the depth having now been extended to several feet.[2]

Supplementing the facts of geology, the phenomenon of volcanism yields important information concerning what we may call the near interior. The existence of volcanoes and the outpouring of vast quantities of hot gases and molten lava furnish direct and striking evidence of conditions many miles below the surface. Additional information of value has been supplied by measuring the temperature of lava lakes, of lava flows and of the gases emerging from fumaroles. Further evidence of a hot interior is derived from the measurement of temperature in deep mines and boreholes. The temperature increases steadily with depth, but for reasons yet unknown the temperature gradient varies within wide limits from place to place in the earth. It may increase as much as 1° C. for each 18 meters or as little as 1° C. for over 100 meters. According to Van Orstrand,[3] the greatest depth attained in any boring is 12,800 feet (in Upton County, Texas); the highest temperature that has been measured is 118° C. in California at a depth of 9,000 feet.

Astronomy yields data of high precision concerning the motion of the earth, from which can be calculated its moment of inertia. The precession of the equinox was discovered by the Greek astronomer Hipparchus in 134 B. C. From the accurately known value of the constant of precession, it follows that the moment of inertia of the earth about the polar axis is 8.06×10^{44} g cm^2. This is a quantity that depends on the distribution of density within the earth. For a given mass, and for a given mean density, the moment of inertia depends on the distribution of light and heavy substances; if there is heavy material at the center and light material at the surface, the moment of inertia would be considerably less than if the central density were smaller than that of the surface. The moment of inertia of a body may be described qualitatively as its tendency to continue

[2] C. S. Piggot, *Bull. Geol. Soc. Amer.*, 47: 675–684, 1936.

[3] C. E. Van Orstrand, personal communication.

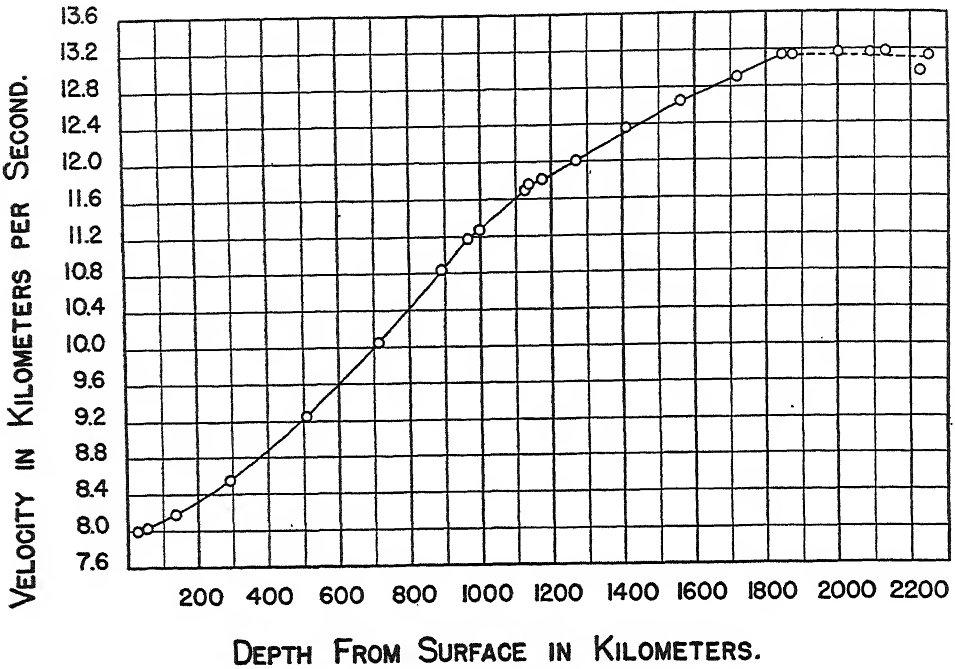

FIG. 1. VELOCITY–DEPTH CURVE

(AFTER REPETTI). SUCH CURVES SUPPLY DIRECT EVIDENCE CONCERNING THE NATURE OF THE EARTH'S INTERIOR.

spinning when once it has been set in motion. It is obvious that a fly-wheel loaded at the center will spin less persistently than if the same load were fastened to the rim. Similarly, the known moment of inertia of the earth allows us to make important deductions concerning the mass or density at various positions from surface to center.

By far the most direct and definite evidence concerning the interior of the earth is supplied by earthquake waves, especially in combination with laboratory measurements on various rocks and minerals. The story has been told before, but it will bear brief repetition. When an earthquake occurs, elastic vibrations of various kinds are generated. One variety travels along the surface and is responsible for the damage caused by large earthquakes. More important for the present purpose are the two varieties that pass through the body of the earth. One of these "through-waves" consists of longitudinal vibrations, analogous to ordinary sound waves in air; the other consists of transverse vibrations, more nearly akin to light waves. Their formation is in accord with the conclusion from the theory of elasticity that any disturbance in an elastic isotropic material should give rise to the two kinds of vibrations, traveling with velocities depending only on the density and elastic constants of the material at each point. Earthquake waves, which have passed through the earth, are recorded by the delicate instruments of the seismologist, who is able to distinguish the several types of waves and to tell with high precision their time of arrival at various stations. From the observations we may construct for each kind of wave a "travel time"-distance curve, which shows for any distance the time required for the vibrations to pass from the earth-

quake center to the recording instrument. The mathematician is now called upon. After subjecting the curve to a remarkable and intricate mathematical analysis he finds the shape of the path along which the wave travels—it turns out to be curved—and finds also the velocity at each point of its path, that is, the velocity at the various depths to which the wave has penetrated in its journey through the earth from focus to station. The recent careful determinations of Repetti[4] are shown in Fig. 1. The particular value of this velocity-depth relation lies in the fact that solely from laboratory measurements of the elastic contents of rocks (to which reference will be made later) we may calculate the wave velocity in various types of rocks, and thence, by comparison with the known velocities at several depths below the surface, make important deductions concerning the nature and composition of the material within the earth. It is as if the earthquake waves, upon arriving at the surface, carry with them a message telling not only how long they have been on the way and how deep they have penetrated, but also how fast they traveled at each point of their path, and finally the nature of the material through which they have journeyed. To be sure, the messages are in code, but happily the code has been deciphered by the ingenious devices of the mathematician.

Turning now to those laboratory measurements that pertain to the present subject, we note first the constant of gravitation, originally determined by Cavendish in the eighteenth century. The most recent published result, that of Heyl,[5] is 6.67×10^{-8} in absolute units. From the measured constant of gravitation we know at once the total mass of the earth, and thence by combination with its volume, the average density of the globe. The value obtained, 5.52, is a very important one to which reference will be made later.

The chemical composition of the rocks in or near the earth's surface has been subjected to exhaustive investigation. It is a striking fact that, although about one thousand different minerals are known, the importance and essential igneous rock-forming minerals number only about a dozen, and that although some 90 chemical elements have been found in or on the earth, 11 elements make up $99\frac{1}{2}$ per cent. of the earth's layers. These elements in order of their abundance are: oxygen, silicon, aluminum, iron, calcium, sodium, potassium, magnesium, titanium, phosphorus and hydrogen. The above conclusions are based on the studies of Washington and others of nearly 10,000 chemical analyses of rocks, which show also that the average igneous rock found at the surface of the earth corresponds to a granite or granodiorite.

Of especial significance is the composition of meteorites. As a result of many analyses of these strange visitors from outer space we now know that they consist largely of impure metallic iron and basic silicates approaching olivine in composition. Absent, or present only in minor amounts, are the characteristic constituents of granite, such as lime, alumina and the alkalis.

An indispensable item in the list of factors from which we hope to reach definite conclusions concerning the earth's interior is the compressibility of rocks. One of the earliest grants of the Carnegie Institution of Washington was to F. D. Adams, at McGill University, for the purpose of measuring the elastic constants of typical rocks.[6] The results obtained were of great interest and value, although the method used was an indirect one and the maximum pressure that was applied to the rock specimens was only a few hundred atmospheres. Subsequently attempts were made by several

[4] Wm. C. Repetti, Dissertation, St. Louis University. (Printed in Manila, 1930.)

[5] P. R. Heyl, *Bur. Standards Jour. Res.*, 5: 1243, 1930.

[6] See F. D. Adams and E. G. Coker, Carnegie Inst. Wash., Publ. No. 46.

investigators to measure the cubic compressibility of rocks subjected to pure hydrostatic pressure. This sort of measurement is beset with many difficulties. The effect of pressure on the volume of solids is very small. For most rocks it is between one and two parts per million per atmosphere, and it is desired to measure this small effect with an accuracy of 1 or 2 per cent. Satisfactory results were obtained several years ago at the Institution's Geophysical Laboratory by the use of high hydrostatic pressures—10,000 atmospheres or more. High pressure, under hydrostatic conditions, has three important advantages: first, because the pressure conforms more nearly to the conditions at great depths below the surface of the earth; second, because the volume changes, which are so small when only one atmosphere is available, are multiplied 10,000 times; and third, because by the use of high pressures we avoid the irregularities that appear at low pressures, especially with coarsely crystalline materials.

For these measurements the so-called piston-displacement method was used. The specimen, usually cylindrical in form, was placed inside a thick-walled cylinder, or bomb, of special steel, where, entirely surrounded by a thin liquid, it was subjected to the desired pressure. A piston with a leak-proof packing was forced into the bomb by means of a press and the pressure thus built up. The amount of movement of the piston is obviously a measure of the volume-change of the material within the bomb. Therefore, by recording the motion, or displacement, for a series of pressures, and correcting for various factors such as the compressibility of the liquid, we obtain finally the compressibility of the specimen.

Although it would be desirable to have similar direct measurements of the rigidity of rocks, a substitute is afforded by the above-mentioned seismologic data, which show that the material at considerable depths is sensibly isotropic and that the elastic constant called Poisson's ratio has the nearly constant value, 2.7. This justifies the use of a simple relation in the theory of elasticity to calculate the rigidity of rocks at high pressures from the compressibility measurements, and thence to calculate the velocities of the transverse and longitudinal vibrations.

Over a period of several years many such measurements and calculations have been made on numerous varieties of granite, diabase and other rocks, and on the common rock-forming minerals. The immediate conclusions from the results were first, that typical rocks had a much lower compressibility, and hence a much higher wave velocity, than had previously been supposed; and second, that except for very low pressures the compressibility of a given rock was merely the average of the compressibilities of its component minerals.

The above-mentioned results were obtained at or near room temperature. Quite recently Birch and Dow at Harvard have been able to carry out measurements at elevated temperatures and thus to supply information concerning the effect of temperature on elasticity and wave speed in rocks.[7]

Brief mention will be made of one other experimental research, which is pertinent to the general subject before us. This is an investigation of the effect of high pressure on the critical temperature at which iron loses its magnetism. It was carried out as a joint effort of two branches of the Institution, the Department of Terrestrial Magnetism and the Geophysical Laboratory. At or above 768° C, iron loses its strong magnetic properties. Any masses of metallic iron within the earth are subjected to the combined effect of high pressures and temperatures. In order to learn something as to the possibility that deep-seated

[7] Francis Birch and Richard B. Dow, *Bull. Geol. Soc. Amer.*, 47: 1235–1255, 1936.

metallic iron, despite a presumably high temperature, should still be strongly magnetic, measurements of critical temperature of magnetization of iron and other ferro-magnetic materials at pressures up to 4,000 atmospheres were carried out. The final result, that the effect of pressure on the critical temperature was practically *nil,* or probably no greater than 0.001° C. per atmosphere (for pure iron),[8] will be referred to presently in connection with the core of the earth.

The Interior of the Earth

The observations and experiments that have been described have not been intended merely as a partial list of unrelated facts in the field of geophysics. They are the main clues by which we are enabled to solve, at least partially, the problem of the structure of the earth's interior. We are now quite certain that the earth consists of three principal regions or zones, the core or central region, the crust or superficial layer and the intermediate zone.

That the material of the earth near its center must be very heavy was one of the earliest conclusions and an excellent example of deductions concerning the interior. Since the average density of the earth as a whole is 5.5, as determined from the measured constant of gravitation, and since the average density of rocks found at the surface is only about 2.8, it is obvious that the central density must be much higher than 2.8—perhaps 8 or 10 or 12—in order for the average to come out right. This high density in the central region might be due to either of two causes: (1) The squeezing of ordinary rock into a much smaller volume under the enormous pressure due to the weight of superincumbent material, or (2) the presence of some other, intrinsically heavier, substance such as a metal. The first alternative was eliminated by using seismologic data to tell us the compressibility of rocks at great depth and then computing the amount by which the volume of silicate rocks could be reduced at depths well toward the center. The maximum by which the density of the material could be increased turns out to be surprisingly large, but entirely inadequate for giving the required average density of the earth. We must conclude, therefore, that it is impossible to account for the high density of the earth by compression alone, and that at and around the center there is a considerable amount of an intrinsically heavy substance. The only reasonable choice is metallic iron. This element is the fourth in order of abundance in ordinary rocks, it is also abundant in the sun as shown by the spectroscope, and in both the metallic and combined form it is the dominant constituent of meteorites. By analogy with meteorites we should expect that the core would not be pure iron but rather an alloy of iron with several per cent. of nickel. The notion of an iron core is not a new one; it was suggested by Dana in 1873, and developed by Wiechert and others in later years. Still earlier the earth was considered to be a great ball of granite, chemically homogeneous throughout, but we have now passed beyond what may be called the granitic era in geophysics, and our present convictions are based on quantitative evidence of the presence of some heavy material at the center.

We may therefore speak with confidence of an iron or nickel-iron core the diameter of which is fixed by seismologic data at 6,400 km, or a little more than one half the diameter of the earth, and confirmed by the moment of inertia determined by astronomical observations. The core is plastic rather than rigid, since it does not transmit transverse earthquake waves; it is non-magnetic and therefore has no appreciable influence on

[8] L. H. Adams and J. W. Green, *Phil. Mag.,* 12: 361–380, 1931.

the earth's magnetism; and the pressure at its center, as is easily calculated, reaches the enormous value, 3,200,000 atmospheres. We know the core to be very hot, but it has not yet been possible to arrive at an entirely satisfactory estimate of the central temperature. From considerations connected with the origin of the earth, the conclusion has been reached[9] that the temperature in the far interior is of the order of 3,000° C.

Although the existence of an iron core is generally accepted by those who have interested themselves in the subject, a few investigators have doubted the validity of this conclusion. Ono, for example, prefers to explain the high central density by the combination of atoms under the conditions of high pressure and temperature to form heavier atoms of various kinds. Others have inclined to the belief that under sufficiently high pressures the structure of all solids will collapse, leaving a material of the same chemical composition and greatly increased density.

This reminds one of the heated discussion carried on some years ago in the columns of a magazine devoted to popular science, as to whether the water at the bottom of the ocean was as dense as cast iron. One faction contended that engineering data showed that materials or structures subjected to sufficient compression in a testing machine invariably failed by crushing, and that at considerable depths in the ocean the water would crush, or cave in upon itself, and thus become as dense as a heavy metal. The principle that was overlooked in this contention was that it is relatively very difficult for pure hydrostatic pressure to make a structure collapse. It is true that we must be on guard against applying the experience and conclusions pertaining to a limited range of pressures and temperatures to the extreme conditions prevailing in the interior of the earth. On the other hand, various considerations indicate that the postulated transmutation of elements and collapse of crystal structure will take place only under pressures and temperatures of a higher order of magnitude than those existing in the earth, that is to say, in the interior of stars rather than planets.

Passing over the intermediate zone for the moment, let us turn our attention to the outer layer, commonly called the crust. This term dates back to the time when the earth was thought to consist of a thin solid crust surrounding a molten interior. But the notion of a true crust floating on a thin liquid is now abandoned, although the word is still used to designate the outer layer, perhaps 40 or 50 kilometers thick, with properties very different from those of the material below it.

From geologic studies it has long been known that the accessible part of the crust consists largely of granite. When the measurements of the compressibilities of rocks, already referred to, were made and the velocity of longitudinal vibrations in typical granites found to be 5.6 kilometers per second, it was therefore a source of gratification to find that this was precisely the speed found by the seismologist for the longitudinal waves in the outermost parts of the crust. From seismologic data we know that this granitic layer varies in thickness from place to place. In continental areas it may be as little as 10 kilometers or as much as 30 kilometers in thickness, while in the great ocean basins it appears to be entirely missing.

Underneath the granitic layer the crust, as indicated by the velocity of earthquake waves passing through this region, is basaltic in composition. There is some evidence for a transition layer intermediate in composition and position, but apparently the crust consists largely, if not entirely, of the granitic and basaltic layers.

[9] Personal communication from Dr. Ross Gunn.

By the mathematical theory of heat conduction the temperature throughout the crust may be estimated if three principal factors are known. These are: (1) the age of the earth, (2) the average amount of radioactive substances in the superficial rocks and (3) the temperature gradient at the surface. The age of the earth, that is, the time that has elapsed from the initial solidification to the present time, is probably not far from 2,000 million years, since minerals have been found, whose age as determined by the lead-uranium ratio is 1,500 million years, and since from astronomical considerations an upper limit of 3,000 million years is indicated. The average amount of radium in the rocks found at the surface is about 3 parts in a million million and the average temperature gradient in undisturbed regions is 0.03° C. per meter. Although these items are all subject to considerable uncertainty, they allow us to construct a useful curve, showing how temperature varies with depth. Especially striking is the conclusion that below about 300 kilometers the temperature is nearly the same as it was originally; the greater part of the earth is now as hot as it was when solidification first took place.

The accessible portion of the crust is almost entirely crystalline. Glassy or amorphous material is comparatively rare. Whether the deeper parts of the crust are crystalline or glassy is a question upon which there is not yet complete agreement. It is worth while to note that the question can not be answered by referring to the temperature-depth curve already mentioned, because the only such curves that have been constructed were based on the supposition that the termination of the era of free convection and the initial cooling of the earth as a solid body were coincident with the freezing of the molten magma.

The intermediate zone 2,000 miles in thickness extends from the bottom of the crust to the top of the iron core (see Fig. 2). Its striking features are the major discontinuities in the velocities of earthquake waves at the upper and lower boundaries. Passing from the crust down through the upper surface of this region, longitudinal waves suddenly increase their speed to 8 kilometers per second. The laboratory measurements on the elasticity of rocks, mentioned above, indicated that only two kinds of rock could support so high a velocity at the moderate pressures appropriate at a depth of about 50 kilometers. These are dunite and eclogite, rocks that are found in few places at the surface of the earth. Weighty evidence pointed to the first of these as the more probable constituent of the intermediate zone, and the conclusion was drawn that the shell consisted of this olivine rock and that therefore the whole earth, except for the iron core and the relatively thin crust, was made up entirely of magnesium iron orthosilicate. It followed that only four elements, silicon, oxygen, magnesium and iron, composed the bulk of the earth's substance, all the other elements being present in minor amounts.

The force of this conclusion has been weakened somewhat by the recent measurements of Birch and Dow, mentioned above, on a specimen of diabase from Vinal Haven. The result obtained for the compressibility leads to a wave velocity equaling that found in the upper part of the intermediate layer, and thus appears to invalidate the argument that the presence of dunite or peridotite in this region is necessary in order to account for the observed velocities of earthquakes below the bottom of the crust. The method used was a linear one, the cubic compressibility being inferred from the change in length of a small rod exposed to pressure, whereas at the Geophysical Laboratory the volume-change, being measured directly, is independent of the degree of isotropy of the material. In view of the fact that the two methods

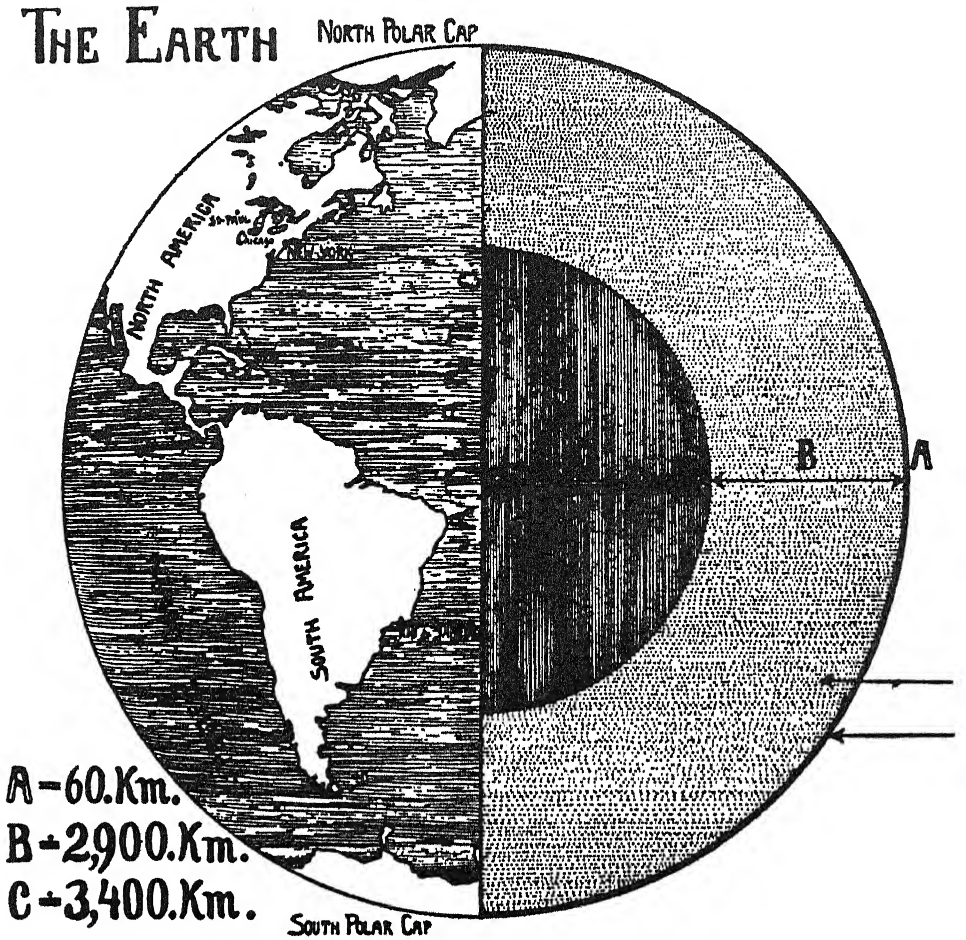

FIG. 2. SECTION THROUGH THE EARTH
(AFTER MOHOROVIČIĆ). *A* IS THE CRUST, *B* THE INTERMEDIATE ZONE, AND *C* THE CENTRAL CORE.

agree remarkably well for non-porous substances such as silica glass and also for the porous rock, limestone, the writer prefers to accept the results of direct volume-change measurement and the conclusions based thereon, at least until measurements by the linear method are made on specimens of diabase cut in three mutually perpendicular directions, and until further measurements by both methods on the same samples of rock become available.

From observations on the tidal deformation of the surface the earth has long been known to be as rigid as steel, and from seismologic data we find that from crust to core the rigidity increases steadily with increasing depth. It is very clear, therefore, that the earth as a whole is "solid"; but whether its substance, particularly in the intermediate zone, is crystalline or glassy is more difficult to decide. From what information we have it does not seem possible that any silicate glass of a composition favorable for remaining permanently in the glassy state can support the requisite wave velocities. Although there may be, and probably are, shallow zones or limited regions of glassy material, the weight of evidence, in the writer's opinion, seems to favor crystallinity for

practically the entire silicate part of the earth. This is a subject for which admittedly there are decided differences in the viewpoints of various investigators. Lack of space prevents a complete discussion of the subject at this time.

Many circumstances, concerning which there is at the moment insufficient time for discussion, indicate that the early history of the earth was as follows: The primitive molten magma consisting mainly of magnesium iron silicates with smaller amounts of other oxides, including water, together with a considerable amount of metallic iron, first separated into two layers—molten iron below and silicate magma above. The silicate layer then began to crystallize at the bottom. As the solid layer increased in thickness, the minor constituents, including water, were concentrated to a greater and greater extent in the remaining liquid. Finally when the liquid layer had been reduced to a thickness of a few tens of kilometers, and was much richer in the originally minor constituents, the crust of the earth was formed.

One of the most cogent reasons for believing that the earth is crystalline is that in no other way can we easily account for the fact that the crust differs so markedly from the interior. Granting that the earth was once molten and well stirred, we apparently must admit that the separation into zones on so large a scale took place either by the falling of a heavy insoluble liquid to the bottom (thus producing the iron core) or by the residuum of a process of crystallization, this residuum becoming the crust.

Concluding Remarks

The problem of the earth's interior has not yet been solved. Although much is known about conditions far within the earth the interior still holds many mysteries. An explanation of the mechanism by which deep-focus earthquakes occur is lacking, and we have no clues as to the underlying cause of the numerous minor discontinuities in the earthquake velocity-depth curves. Better knowledge of the temperatures within the earth would be of great utility and, especially, some basis for a more precise estimate of the original temperature of the molten earth. A general understanding of the great intermediate zone is essential before we can make satisfactory progress in investigations of the crust.

But although much remains for the future, we are able to point to a number of definite accomplishments during the past several years. These are: (1) precise measurement of the elastic constants of rocks and the determination of the speeds with which elastic waves will travel through them; (2) the identification of the upper half of the crust as a granitic layer; (3) a demonstration that the core of the earth contains a heavy material such as iron; (4) an explanation of the two major discontinuities within the earth in terms of the elastic constants of typical rocks; (5) the supplying of strong evidence that large masses of iron may exist in the interior without influencing the earth's magnetic field, and (6) the establishment of an improved temperature-depth curve for the crust and the region immediately below it.

In attempting to paint a picture of the deeper parts of the earth, the best we can do at present is to draw the outlines. Perhaps future developments may enable us to make a bolder drawing and even to fill in something of form and color.

PHYSICS IN THE ATTACK ON THE FUNDAMENTAL PROBLEMS OF GENETICS[1]

By Dr. H. J. MULLER

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THE evidence obtained by geneticists indicates that it is in the tiny particles of heredity—the genes—that the chief secrets of living matter as distinguished from lifeless are contained, that is, an understanding of the properties of the genes would bridge the main gap between inanimate and animate. Such a study would be of intense interest from the point of view of physics as well as of physical chemistry and organic chemistry, for it is already known that these genes have properties which are most unique from the standpoint of physics and of the sciences related to physics. So peculiar are these properties that physicists, when first confronted with them, often deny the possibility of their existence. Yet there is really no doubt of the truth of the biologists' findings concerning the genes, so it may well be that an elucidation of them may throw light not only on the most fundamental questions of biology, but even on fundamental questions of physics as well. I am therefore making this plea to physicists in the hope that they will interest themselves more actively in these problems, of such vital importance to both our fields.

To grasp the problems involved in the study of the gene it should first be explained that genes are particles of submicroscopic volume, probably of the order of about one twentieth of a micron in length, and considerably less in their other diameters, probably of protein composition (see below), and bound to one another in line, single file, so as to form solid threads ("chromonemas"). These threads are usually many microns long and thus comprise thousands of these genes, each gene in the chain usually being different in its composition and chemical function in the cell from every other gene. The nucleus of the cell contains a specific number of these gene-chains, often in more or less spirally coiled form. All these genes not only exist in the reproductive cells and constitute the ultimate particles of heredity, but they also exist in all the other cells of any living body and, as mentioned in the preceding, they probably constitute the ultimate particles of life itself. Through the varied reactions of the different kinds of genes with the various surrounding materials of the protoplasm, the basis is laid for the production of the various chemical substances and for the carrying on of the various chemical processes, and for the determination of the various morphological structures peculiar to each cell.

Now, the most spectacular property of the gene, from the standpoint of physics, is its property of *specific auto-attraction* of like with like. In explanation of this, no physicist has ever yet been able to offer any plausible hypothesis. The attraction in question has an opportunity of exerting itself, owing to the fact that in most cells there exist at least two gene-chains of each kind (one having been originally derived from the mother of the organism, the other from the father). That is, if we may represent the genes in one of the gene-chains in a cell as A, B, C, D, etc., in that

[1] Paper presented to session on physics of the Academy of Sciences of the U. S. S. R., Moscow, March, 1936.

order, then there is present somewhere else in that cell another gene-chain having genes of identical composition: A, B, C, D, etc., in the same order. Besides this, there are other gene-chains which we may represent as L, M, N, etc., T, U, V, etc., and of each of these long chains or chromonemas the cell contains two representatives. Now, under certain conditions, it becomes evident that each gene forms the center of a specific field of attractive force, for then gene A tends to come together with the other A, B with the other B, (L with L, M with M, and so on). We know that this must be true, even though the individual genes are too small for us to see, because we can see that the gene-chains as a whole tend to come together in this way, like with like, so that one ABCD comes into side-by-side contact ("conjugates") with the other, one LMN with the other LMN, etc. They always do this in such a way as to be oriented in the same direction, the A end of one chain next to the A end of the partner chain, not next to the other end. Moreover, if through some prior accident one or more of the chromonemas (gene-chains) has previously become broken at any point (or even if several breaks have occurred and the fragments have then united together again in a different way than before, so as to have the genes arranged in a new order), still the corresponding segments tend to come together, like with like. Thus the attraction is in no wise a property of the chain as a whole but purely of the individual, constituent genes.

Unlike the ordinary forces of adsorption known to the physical chemists, these gene forces are of such range as to act over visible microscopic distances. In doing so, moreover, they must in some way interpenetrate one another in many directions, since the forces of attraction of many genes must be traversing the same space at the same time. And despite this interpenetration, these forces must somehow preserve their directions and their specificities. It is probable that this force of auto-attraction exists, to some extent at least, at all times, but it is sometimes prevented from expressing itself by the simultaneous existence of a non-specific repelling force of a different nature, the latter probably caused by electrical charges. It has not yet been found feasible under the conditions of biological work to make quantitative studies, after the physicist's fashion, of the nature of the force of gene attraction: studies of its variation of intensity with distance; of the effect of varying conditions upon it; of its direction; of its speed of propagation; of the possible interference with one another of the forces emanating from different genes; of its possible polarization, etc. It is probable, however, both from theoretical considerations and from the observed tendency of like strands to conjugate by twos, even when more than two are present, that the force does not issue in a radially symmetrical manner but that a certain side-surface of the gene tends to attract a specific side-surface of the other, like gene. We would like physicists to search the possibilities of their science and tell us what kind of forces these could be, and how produced, and to suggest further lines of approach in their study.

It is not unlikely that a solution of the above physical mystery would also throw much light on the nature of that property of the gene which is most peculiar and spectacular from the standpoint of the chemist. This second peculiar property is that of *auto-synthesis*. That is, each gene, reacting with the complicated surrounding material enveloping all the genes in common, exerts such a selectively organizing effect upon this material as to cause the synthesis, next to itself, of another molecular or supermolecular structure, quite identical in composition with the given gene itself.

The gene is, as it were, a modeller, and forms an image, a copy of itself, next to itself, and since all the genes in the chain do likewise, a duplicate chain is produced next to each original chain, and no doubt lying in contact with a certain face of the latter. This gene-building is not mere "auto-catalysis," in the ordinary sense of the chemist, since reactions are not merely speeded up that would have happened anyway, but the gene actually initiates just such reactions as are required to form precisely another gene just like itself; it is an active arranger of material and arranges the latter after its own pattern.

The analogy to crystallization hardly carries us far enough in explanation of the above phenomenon when we remember that there are thousands of different kinds of genes, *i.e.,* of genes having different patterns, in every cell nucleus, and that each of these genes has to reproduce its own specific pattern out of surrounding material common to them all. When, through some micro-chemical accident, or chance quantum absorption, a sudden change in the composition ("pattern") of the gene takes place, known to biologists as a "mutation," then the gene of the new type, so produced, reproduces itself according to this new type; *i.e.,* it now reproduces precisely the new pattern. This shows that the copying property depends upon some more fundamental feature of gene structure than does the specific pattern which the gene has, and that it is the effect of the former to cause a copying not only of itself but also of the latter, more variable features. It is this fact which gives the possibility of biological evolution and which has allowed living matter ultimately to become so very much more highly organized than non-living. It is this which lies at the bottom of both growth, reproduction and heredity. We would like the physical chemists to work on this problem of auto-synthesis for us, but it may well be that a further elucidation, by the physicists, of the property of auto-attraction of genes would greatly help in the explanation of this auto-synthesis also.

The reason why I think there may be a relation between the two properties is this. If the attracting principle of like for like, which we already know to be possessed by the gene considered as a whole, extend also to more elementary parts of the gene, to "blocks" whose differences in arrangement constitute the specific differences in gene pattern whereby one gene differs from another and which form the basis of the mutational changes, then, if we suppose that representatives of these more elementary "blocks" exist in scattered disorganized form in the space surrounding the genes, it can be seen that each gene-part or "block" would tend to attract to itself another, like part, and so a second group of parts would gather next to the original gene in the same pattern as in the latter, in much the same way as, on a still grosser scale, each chromonema as a whole builds up a second chromonema, having its individual genes identical with and arranged in the same order as in the first one. If, then, the auto-attraction holds not merely for genes as a whole but also for gene-parts the auto-synthesis of a gene as a whole would be largely explained in terms of this auto-attraction. (Of course we should in this case still be left with the problem of the synthesis of the gene-parts, but this might be simpler as they might be of relatively limited number). It is tempting to think that this suggestion is true, in view of the great uniqueness both of the property of auto-attraction and of auto-synthesis, and in view of the possession by both of certain common, striking features: namely, auto-specificity, and the property of retaining this auto-specificity in spite of the changes called mutations. For it is to be noted that in the case of the auto-attraction also, we must suppose

that when one of those rare changes called a mutation occurs, the new gene has a changed kind of attraction, such that it now attracts preferentially another gene having a pattern like that of its new self, not one with a pattern like that of its old self. Thus, the auto-attraction of the gene, just like its autosynthesis, must depend upon some fundamental features of the gene structure, which persists despite the secondary changes in pattern (mutations). And this fundamental feature must be instrumental not only in producing an attractive force in general, but in determining that this attraction shall somehow express, in its specificity, both the fundamental structure itself and also those other details of pattern which vary independently of this fundamental structure. In the face of such problems, the biologists must perforce call to the physicists and the physical chemists.[2]

In the solution of these problems, and of the general problems of gene composition, one possible line of approach might be through the study of x-ray diffraction patterns. Preliminary studies of this nature upon the proteins of hair have been made by Astbury and others,[3] at Leeds, but studies of such proteins may be a far call from the study of the gene. But it may be possible for gene material to be used in such investigations. For there exist, in some of the cells of flies, bundles of identical chromonemas conjugated together in hundreds, and these bundles are so large that they might even furnish material for an x-ray diffraction study if we had people of sufficient physical training, combined with biological interest, to tackle such a job. Of course, there may be much material extraneous to the genes themselves, contained in such a bundle of chromonemas, but they are at least more nearly the material we are seeking than is any other morphologically separable constituent of the cell. It might also be objected that every gene is different from every other, along the length of the chain, and that therefore we would be studying, at best, a great mixture of gene materials. Nevertheless, as above stated, there must be much in common to the structure of all genes and these common features might give results in such a study. Needless to say, it would also be desirable to have parallel studies on such material carried out by the methods of the chemists.

In the past year the opportunity has also arisen of obtaining from another source material which may serve our present purpose. This possibility arises out of the discovery by Stanley and Loring,[4] that the substance (or "organism") causing the so-called mosaic disease of tobacco, and likewise that of tomato (and doubtless of various other higher organisms), may be obtained in crystalline form, apparently as a pure protein. We judge that this material has the properties of a gene, inasmuch as it can reproduce itself, *i.e.*, it can undergo autosynthesis when present in a cell and it is probably mutable, since different "species" of it are known. We may provisionally assume, then, that it represents a certain kind of gene. The weight of its giant molecule is of the order of several million, and this agrees as well as could be expected with the very approximate estimates of size hitherto made for the genes of flies. As this substance can be obtained in some bulk and in apparently

[2] Discussions of gene auto-attraction and autosynthesis have been given by the author in the following papers: H. J. Muller, *Am. Nat.*, 56: 32–50, 1921; *Proc. Int. Cong. Plant Sci.*, 1: 897–921, 1929; "The Enigma of the Gene and of Its Mutation," address at Franklin Institute, Philadelphia. (MS. unpublished, 20 pp), December, 1928; *Am. Nat.*, 69: 405–412, 1935.

[3] W. T. Astbury and R. Lomax, *Jour. Chem. Soc.*, June, 1935. W. T. Astbury and W. A. Sisson, *Proc. of Royal Soc. London*, 150, pp. 533–551, July, 1935. W. T. Astbury and H. J. Woods, *Philo. Trans. Royal Soc. London*, 232, pp. 333–394, June, 1933.

[4] W. M. Stanley, *Science*, 81: 2113: 644–645, 1935; W. M. Stanley and H. S. Loring, *Science*, 83: 2143: 85, 1936.

pure form, it will be very important to carry on an active investigation of it not only from a purely chemical standpoint, but also from a physical standpoint, with special reference to the problems above raised. Among other things, x-ray diffraction studies of it should be attempted by competent specialists in this field of physics.

I have tried in the above to lay emphasis on the most outstanding problems of physical and physico-chemical science which the geneticist has found himself confronted with, and which he is practically unable to attack by means of the methods familiar to him. I have omitted a discussion of the very important problem of the way in which changes in genes —mutations—occur. Although this is a matter in which the aid of physicists is invaluable to us, the methods of genetics and physics combined—investigations of the frequency and character of mutations under varying conditions and with varying doses of irradiation—have already given valuable results. They have shown, for example, that the mutations produced by high frequency irradiation are the results of single ionizations, and that the whole process from ionization to mutation must be rather sharply circumscribed in space. Through such studies we may be able to learn more about the nature of these variable features of the gene pattern, which determine the specific properties of one gene as distinguished from another one, and which are in a sense independent of those fundamental features of its composition which give it its properties of auto-attraction and auto-synthesis. It is in this field of mutation that the physicist is to-day most actively and fruitfully helping the geneticist.

There are also many other physical questions before the geneticist, such as that of the nature of the non-specific repulsive force which exists between chromonemas, especially at certain periods and in certain portions of them; the nature of the coiling and uncoiling of these threads and of all the various motions and physical and physico-chemical changes which they undergo in their complicated life history. There is the question of what holds the genes together end to end, in single rows; how these chains may become broken and the pieces stuck together again, etc. There is the question of the manner in which they produce their effects upon other substances in the cell—probably by a kind of enzyme action—so as to act as the determiners of the properties of the cell and of the organism as a whole. And there is the problem of the so-called "position effect," *i.e.*, the fact that the arrangement of the genes in the chromonema with respect to each other has an important influence upon the kind of effects which these genes exert upon the surrounding substances. Possibly this "position effect," too, is related to the property of gene attraction. All these questions, however, important though they be, nevertheless seem secondary in comparison with the problems of auto-attraction and of auto-synthesis themselves, and of the structure giving rise to them, and with the related problem of the nature of those changes (mutations) which the gene undergoes, which do not disturb these two properties. It is becoming recognized nowadays that the gene is the basis of life. These two properties, including the fact of their undisturbability by mutation, lie at the basis of the gene. The geneticist himself is helpless to analyze these properties further. Here the physicist as well as the chemist must step in. Who will volunteer to do so?

THE SENECA SOCIETY OF FACES

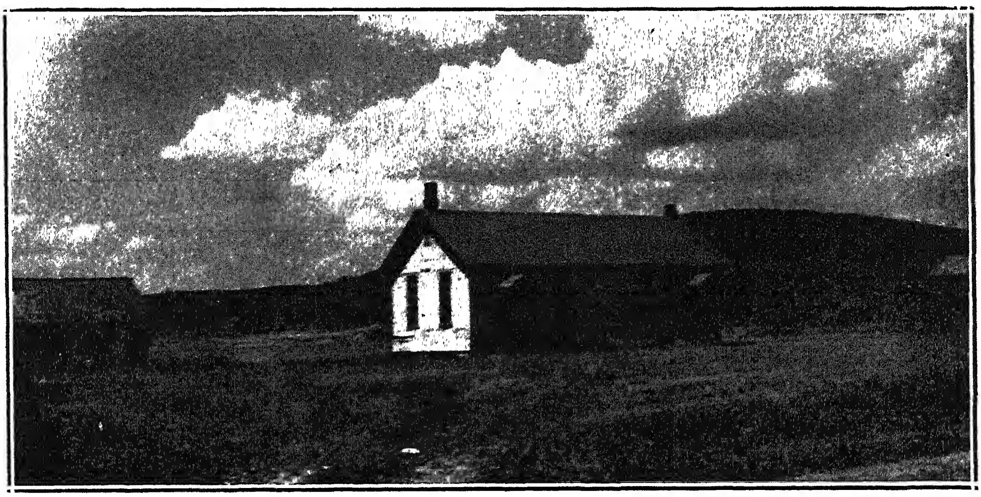
By WILLIAM N. FENTON

U. S. INDIAN SERVICE, TONAWANDA INDIAN RESERVATION, AKRON, N. Y.

FOUR communities of Indians who live but a day's journey from New York City still put on wooden faces in order to drive disease from their settlements. At the Onondaga Reservation near Syracuse and on the three Seneca reservations neighboring Buffalo, there are modern Iroquois villages which still maintain old customs. The "real or longhouse people" reside about ceremonial structures called longhouses at Onondaga, Tonawanda, Coldspring on the Allegheny River and at Newtown on Cattaraugus Reservation. Some of the Iroquois tribes moved west of the Niagara River into Canada at the close of the American Revolution. There, on Six Nations Reserve along Grand River in Ontario, are Onondaga, Seneca and Cayuga longhouses which are still active. The New Yorker who wishes to catch glimpses of the past may, if he is accepted, witness ancient ceremonies almost in his dooryard without going to the Southwest.

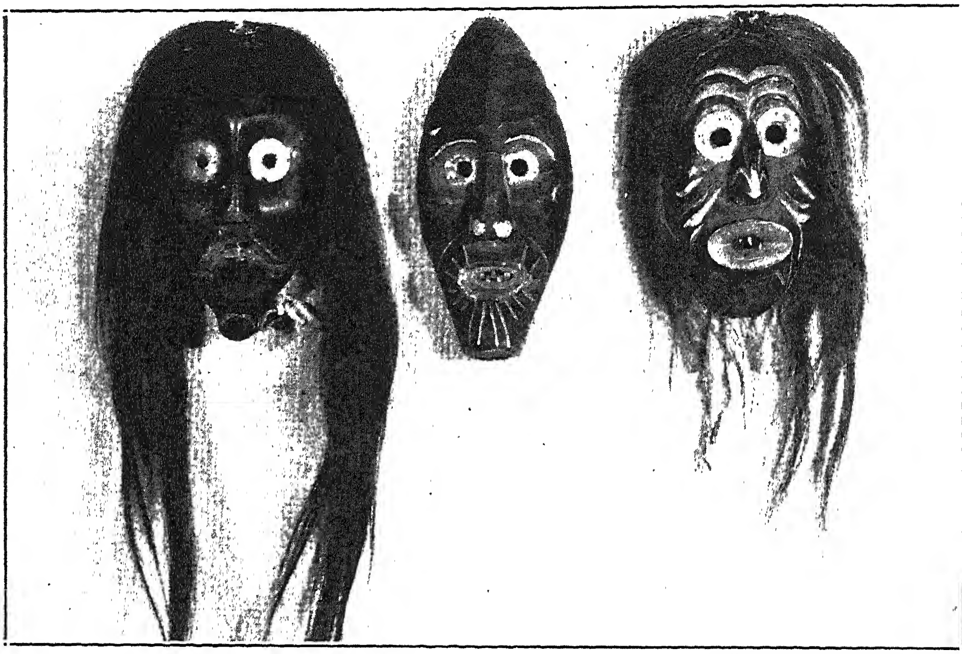
THE WOODEN FACES

Wooden masks from the Iroquois are prominently displayed in exhibits of eastern museums. A few museum visitors may appreciate that the weird human likenesses which mock them from the show-cases are actually memorials to generations of nightmares. They are wooden portraits of several types of mythical beings whom the Seneca say only a little while ago inhabited the earth. The Seneca term for one is "Face" (gagǫ́hsa'); the Onondaga call him "Hunchback" (hadu'í'), and they are called "False Faces" in literature. Iroquois hunters when traveling in the forests frequently met strange, quasi-human beings. Later, these forest folk



THE SENECA LONGHOUSE AT COLDSPRING ON THE ALLEGHENY RIVER.

AT COLDSPRING AND OTHER CONSERVATIVE IROQUOIS COMMUNITIES, THE "REAL OR LONGHOUSE PEOPLE" LIVE CLUSTERED ABOUT A DANCE-HOUSE, CALLED THE LONGHOUSE, WHERE THEY GATHER FOR SOCIAL AND RELIGIOUS MEETINGS.



Buffalo Museum of Science.

ANCIENT MASKS, PRESUMABLY FROM THE CANADIAN IROQUOIS.

HEAVY CARVING, PROMINENT CHINS AND WRINKLES INLAID WITH COLORED PIGMENTS ARE CHARACTERISTIC ART OF THE MIXED CAYUGA AND ONONDAGA TRIBES AT GRAND RIVER AND, LESS FREQUENTLY, THE ONONDAGA AT SYRACUSE.

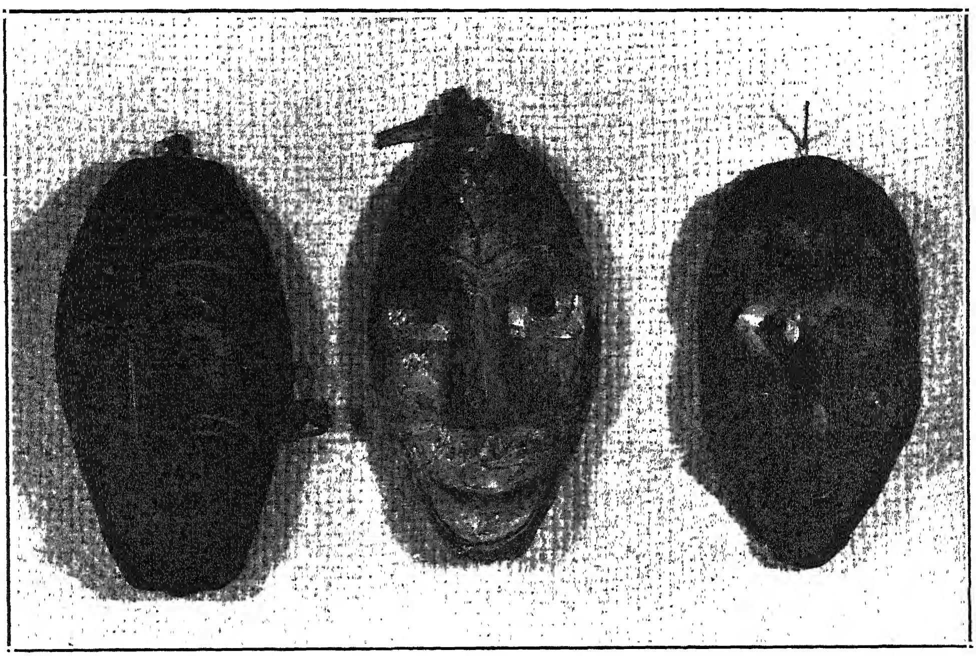
appeared to the hunters in dreams. They agreed not to molest humans, saying that they merely wanted Indian tobacco (*Nicotiana rustica*) and mush to be made from the white corn meal which hunters and warriors carried.

The Faces claimed to possess the power to control sickness. They instructed the dreamers to carve likenesses in the form of masks, saying that whenever any one makes ready the feast, invokes their help while burning Indian tobacco and sings the curing songs, supernatural power to cure disease will be conferred on humans who wear the masks. The dancers should carry turtle rattles and speak a weird, unintelligible nasal language. They can scoop up glowing embers in their bare hands, without suffering burns, in order to blow hot ashes on the sick person. The masks are as varied as the visions and the artistic whims of the individual craftsmen who have carved them from single blocks of living basswood.

Natives themselves are confused when asked to classify False Faces. One old Seneca informant, Henry Red-Eye, told me there are as many False Face types as there are different people. Some are portraits of youths; others are of old men who have long, white hair and wrinkled faces. There are angry individuals with broken noses and mouths skewed to one side as if they had suffered paralytic strokes who are apt to sweat and cause an owner illness, if he neglects to supplicate them with tobacco offerings. Some have distended, open lips as if they were blowing ashes; a few with standing hair and raised eyebrows are whistling and merely want tobacco, while others protrude red tongues or laugh, revealing irregular rows of wooden or

bone teeth. Their similarities are only those which the culture has prescribed in dreams.

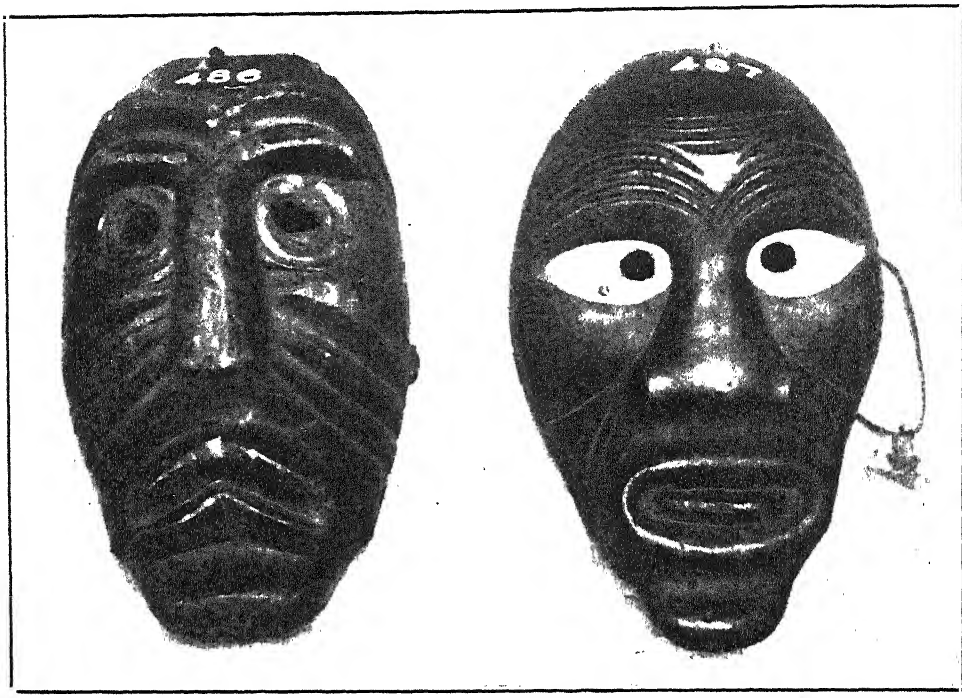
Tradition has dictated the forms which the faces assume in visions, and the features which the craftsmen emphasize when carving, the very features which the Indians mention when describing the original forest folk. It is sufficient for the carver to single out particular features of the face for artistic expression; the face portrays the being, and the wearer must dramatize his other attributes: his erect or slouching gait, his awful mien and the nonsensical, nasal speech which he accompanies by shaking a rattle. To the Indians, the total effect is both terrifying and extremely humorous. In general, the masks have deep-set eyes, rendered bright by metal sconces, and large, frequently bent noses. The arched brows are deeply wrinkled and divided above the nose by a longitudinal crease or a comb of spines, which one Seneca calls "Turtle-tail," because they resemble the processes on a mud-turtle's tail. Thick, distended lips protrude beyond the nose, and a series of modifying wrinkles augment the distorted expression. Cheek bones are sometimes suggested, and a prominent chin, common on masks from Grand River, serves as a convenient grip for the wearer to adjust the mask to his face. The face is framed by a long wig, usually cut from black horsetails which fall on either side from a part in the middle of the forehead; but anciently, corn-husk braids or buffalo mane served as hair. Masks are commonly painted red or black.



Buffalo Museum of Science.

ANCIENT IROQUOIS MASKS FOR BEGGING TOBACCO, PROBABLY SENECA.

IROQUOIS HUNTERS MET THESE QUASI-HUMAN BEINGS IN THE FORESTS, DREAMED OF THEM AFTERWARD AND CARVED THEIR FACES ON LIVING TREES. THE FROWNING FACE, WERE IT ADORNED WITH LONG HAIR, MIGHT APPEAR AS A DOOR-KEEPER AT A CURING RITUAL. THE SECOND IS A MERRY BEGGAR, AND THE THIRD IS WHISTLING; THEY MERELY WANT TOBACCO.



Collection of the Onondaga Historical Society.

NINETEENTH CENTURY ONONDAGA MASKS.

DECOST SMITH, THE ARTIST, WHILE ON A VISIT TO ONONDAGA CASTLE IN THE EIGHTIES, DISCOVERED MASKS IN AN INDIAN'S GARRET, COLLECTED THEM FOR HIS FRIEND, THE REV. WM. M. BEAUCHAMP, AND LEARNED THAT THE MASKED SOCIETIES WERE STILL ACTIVE.

NARRATIVES OF EARLY TRAVELERS

Although the Iroquois have felt three centuries of white contact, the earliest travelers mention masks and describe masked ceremonies which suggest modern rituals. The Jesuits wrote home accounts of face painting and masking, comparing the Indians with the masqueraders of provincial France. The author of Van Curler's journal, who visited the Mohawks and Oneidas about 1635, tells us that a chief showed him his idol, which was a head with teeth sticking out, and that he kept it draped in a red cloth. This is reminiscent of the modern custom of covering masks when putting them away. The "Relation" for 1637 describes the False Faces and their Husk Face doorkeepers among the Hurons. In a dance to drive away pestilence, "all the dancers were counterfeits of hunchbacks, with wooden masks the whole ridiculously made, and each a staff in hand; behold an excellent medicine. At the end of the dance, at the order of the sorcerer *Tsondacoüané*,[1] all the masks were hung at the top of a pole at the top of each cabin, with the straw men at the doors." The next night they hung "the wooden masks and strawmen above each cabin." At another time, they put "a sack on the head, pierced only at the eyes."[2]

The latter may be "Longnose," the

[1] godęčoni—she sponsored the ritual.
sadęčoni—you sponsored the ritual > you sponsor.

[2] Citations from William M. Beauchamp, New York State Museum, *Bulletin* 89, p. 184, New York State Education Department, Albany, 1905.

Kidnapper. The Jesuits, Dablon and Chaumonot, who witnessed the mid-winter festival at Onondaga during 1656, do not mention masks but describe their host, covering himself with corn husks from head to foot, who went accompanied by two women with blackened faces and bodies covered with two wolf skins. Each woman carried a club or a great stake.[3] Beschefer, who accompanied De Nonville's expedition to the Seneca, wrote in the "Relation" of 1687 to Villermont:

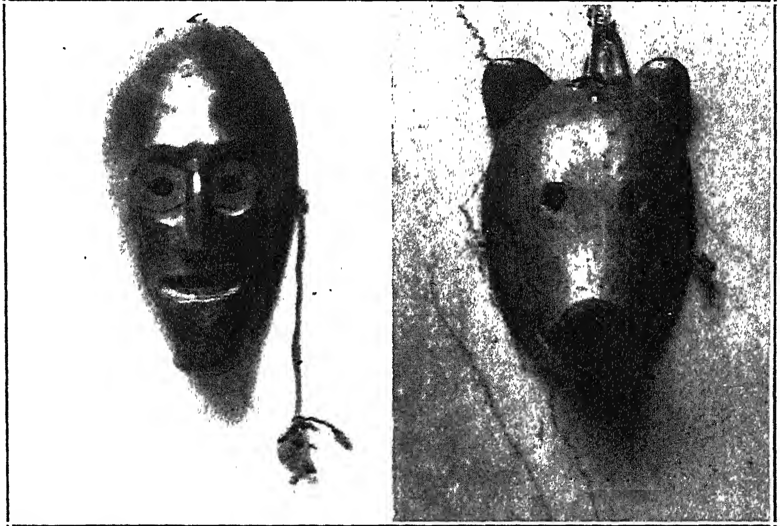
> I was mistaken when I told you that the Iroquois wore no masks. They make some very hideous ones with pieces of wood, which they carve according to their fancy. When our people burned the villages of the Tsonnontouans (Seneca), a young man made every effort in his power to get one that an Outaouae (Ottawa) had found in a cabin, but the latter would not part with it. It was a foot and a half long, and wide in proportion. Two pieces of a kettle, very neatly fitted to it and pierced with a small hole in the center, represented the eyes.[4]

Beauchamp holds that since the Seneca had one Huron town after 1648 that the Huron may have introduced the False Face Society to the Seneca, from whence it spread through the other nations of the Confederacy. Lafitau, who bolstered his own observation with the earlier "Jesuit Relations," mentions masks made from the bark of trees in his "Customs of the American Savages."[5] John Bartram, the Philadelphia naturalist, recorded an unmistakable description of a False Face

[3] "Jesuit Relations," Vol. 42, p. 154 (Thwaites edition).

[4] Beauchamp, *op. cit.*, p. 184.

[5] P. F. Lafitau, "Moeurs des Sauvages Amériquains," 2 vols. Paris, 1724, Vol. I, p. 368.



Joseph C. Greene Collection, Buffalo Historical Society.

THE CLASS OF BEGGAR MASKS IS MOST PLASTIC.

(*Left*). Masks more nearly resembling humans, like this one from Chief Ely S. Parker, U. S. A., which had its face decorated with triangles and crescents (illustration does not reveal the peculiar face painting) for some occasion, and wears a tobacco offering to attest its curing power, have gone out of use at Tonawanda.

(*Right*). With the disappearance of the bear, the pig has become the principal feast animal among the remnant Iroquois, and the pighead has acquired a reflected holiness by association with the rituals of medicine societies. The pig mask, perhaps derived from masks representing the bear, has no special function among the Seneca.

beggar who kept him awake at Onondaga in 1743.

> We were entertained by a comical fellow, disguised in as odd a dress as *Indian* folly could invent; he had on a clumsy vizard of wood colour'd black, with a nose 4 or 5 inches long, a grinning mouth set awry, furnish'd with long teeth, round the eyes circles of bright brass, surrounded by a larger circle of white paint, from his forehead hung long tresses of buffaloes hair, and from the catch part of his head ropes made of the plaited husks of *Indian* corn; I can not recollect the whole of his dress, but that it was equally uncouth; he carried in one hand a long staff, in the other a calabash with small stones in it, for a rattle, and this he rubbed up and down his staff; he would sometimes hold up his head and make a hideous noise like the braying of an ass; . . . In my whim I saw a vizard of this kind hang by the side of one of their cabins to another town.[6]

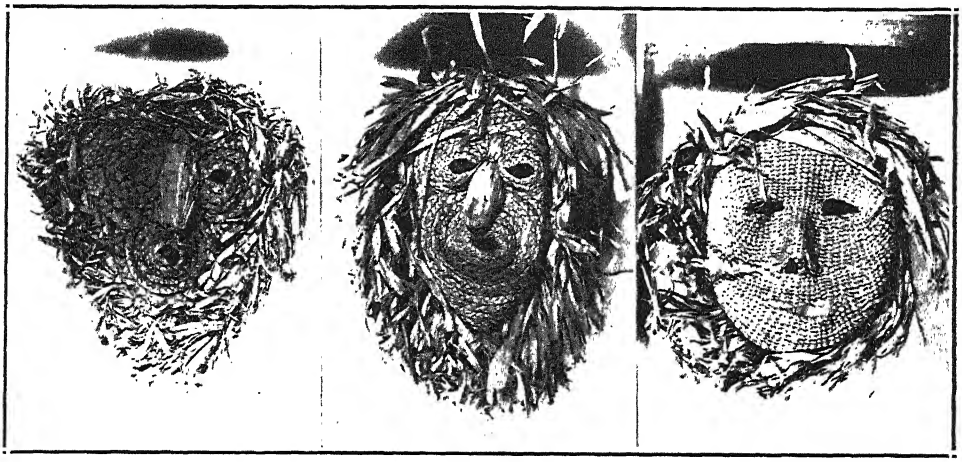
Probably a custom as wide-spread over the world as dressing in masks to impersonate other beings permits us to assume that the Iroquoian custom of wearing False Faces sprang from their own culture, where it became so firmly imbedded that, despite three hundred years of buffeting by white contact, the masks have maintained standards prescribed in the original legends. The masks show little fundamental change from generation to generation. except that they become increasingly ornate or grotesque when influenced by the adoption of better tools or the degeneration of the wood carver's art; and masks portraying a pig, the Devil, and such amusing figures as Mickey Mouse, Felix Cat and Charlie Chaplin have encroached only on the group of faces designed to elicit laughter—the class of beggar masks—which is the most plastic.

The Husk Faces

Besides the wooden False Faces, cornhusk masks and buckskin or cloth masks represent two other classes of beings. The technique of twining and braiding corn husks in the manufacture of shoes, mats and dishes is ancient among the Iroquois peoples. Nevertheless, the Husk Face Society is probably no older than sewing braided corn husks for seats and foot-mats, since the Husk Faces and the beings which they represent are named for the mats (gadjí·sa'). A person awaking with his hair standing awry, like the pile of a foot mat, is said to look like gadjí·sa'. The Husk Faces look like door-mats, the only difference being that the masks have holes for the eyes and mouth. The Husk Faces are a race of agriculturists. They dwell on the other side of the earth in a ravine where they till their fields amid high stumps. Coming from the East every new year, they visit the Seneca longhouses during two nights of the mid-winter festival. Preceded by runners, they finally arrive amid a great din of beating the building with staves, stop the dances and kidnap a chief for interpreter. As messengers of the three sisters—corn, beans and squash—our life supporters, they have great powers of prophecy. The interpreter relates the message of the old woman, their leader, that they are hurrying westward to hoe their crops. In fields about their houses they grow huge squashes; the corn has giant ears and string-beans climb up poles to heaven. Some of their women have remained home to tend to crying babies. Recently in their country there is employment on public works projects. These statements are accepted as an augury of fertility. They request the privilege of dancing with the people. All their company are men, but some dress as women and participate in the dances as if they were women.

The Husk Face Society is by no means as well integrated or prominent as the False Face Society, although they share certain functions. Unlike the False Faces, they are mutes and only puff as

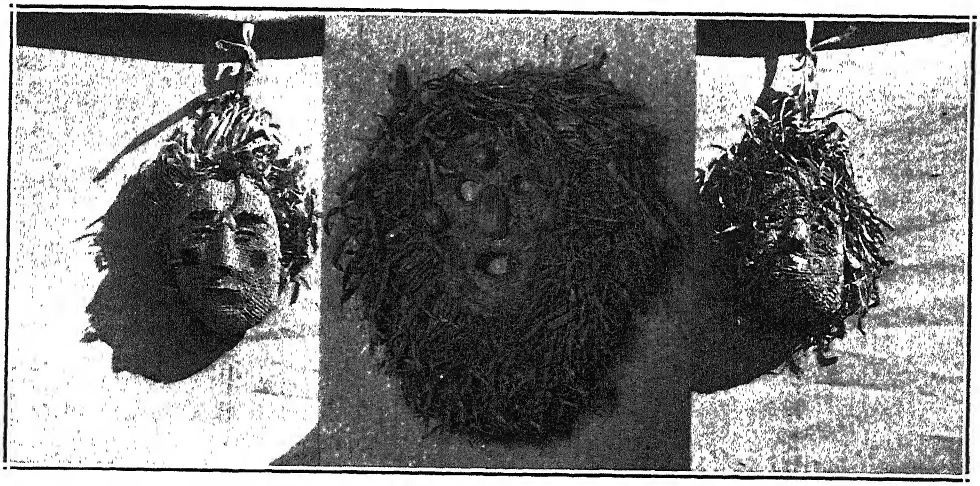
[6] John Bartram, "Observations on the Inhabitants, Climate, Soil, Rivers, Productions, Animals . . . in Travels from Pennsilvania (sic) to Onondaga, Oswego and Lake Ontario." London, 1751 (reprinted at Geneva, N. Y., 1895), p. 43.



Fenton Collection.

THE HUSK FACES REPRESENT A FARMING PEOPLE.

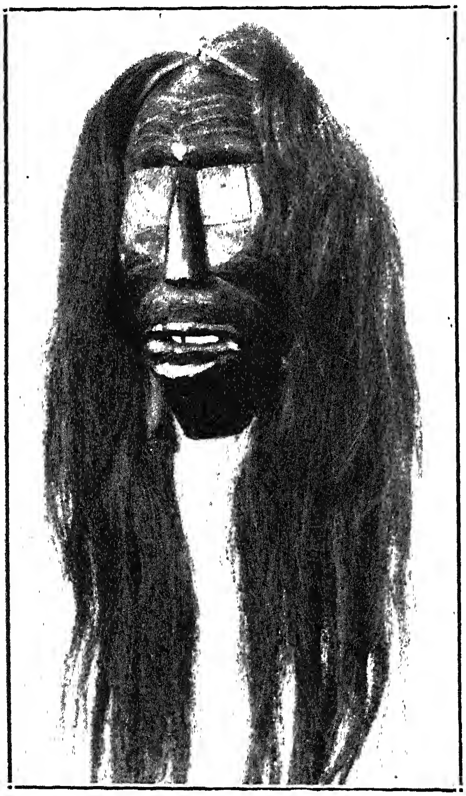
THE FACES OF THE BEINGS WHICH THE HUSK FACES REPRESENT ARE SAID TO LOOK LIKE FOOT-MATS OF BRAIDED CORN HUSKS. IN THE DEAD OF WINTER, A COMPANY OF MASQUERADED MEN AND BOYS DRAMATIZE THEIR VISIT TO THE LONGHOUSE TO FORECAST BOUNTIFUL CROPS AND THE BIRTH OF CHILDREN DURING THE FOLLOWING YEAR. INFORMANTS RECOGNIZE THESE MASKS FROM COLDSPRING AS AN OLD GRANDFATHER (*left*), A GRANDMOTHER (*middle*), AND A YOUNG WOMAN (*right*), SINCE IT HAS LONGER HAIR AND THE TWINING TECHNIQUE IS FREE OF WRINKLES.



THE HUSK FACES LINGER AND DANCE WITH THE LONGHOUSE PEOPLE.

(*Left*). A SENECA PAINTS A SPOT OF RED ON EACH CHEEK WHEN GOING TO A FESTIVAL AT THE LONGHOUSE. THIS TWINED HUSK MASK BELONGS TO THE GREAT PUBLIC RITUALS OF THE HUSK FACE SOCIETY AT COLDSPRING LONGHOUSE. (*Middle*). AT CATTARAUGUS, THE MASKS OF FINE BRAID WITH BUNDLES HUNG ON THEIR CHEEKS REPRESENT FEMALES (PEABODY MUSEUM, YALE UNIVERSITY). (*Right*). THE ROUGH TWINING SUGGESTS AN OLD MAN.

they run with great leaps. They have their own tobacco invocation, a medicine song, and dance about the staves which they carry. They also have the power to cure by blowing hot ashes; but in Canada, they sprinkle water on their patients. They like tobacco, but they prefer popcorn at Allegany and dumplings at Newtown and Tonawanda, instead of mush. When four suddenly appear racing between the houses, they may be signalling the approach of the False Face Company. They will loiter, policing the premises until the Common Faces depart. Relatively few Indians belong to their society, and set a kettle down for them to renew an old dream, but many put on their masks for the public longhouse rituals, and others join them in social dances at the end of the line.[7]



Buffalo Museum of Science.

AN OLD TYPE OF FACE WHICH APPEARS AT COLDSPRING AND GRAND RIVER.

LONGNOSE, WHO KIDNAPS NAUGHTY CHILDREN

The Iroquois and their Algonquin neighbors use buckskin masks to impersonate cannibal clowns who sometimes kidnap naughty children. The Seneca call this clown "Longnose" (hagónde·s) because of his elongated proboscis. He is the Indian bogey-man. He chases bad children when the old people are sleeping. He mimics them, crying out as he runs after them. But the old folks do not wake up, since he has bewitched them in order that they will remain sleeping. This goes on all night until the child gives up and agrees to behave, or else Longnose makes away with the child, carrying him off in a huge pack-basket. It is not right to whip little children. Stubborn children who will not go to bed are sometimes sent out at dusk to meet Longnose, impersonated by a relative wearing a cloth mask. The child immediately runs into the house. Neither is it right to use the great wooden masks belonging to the medicine society for scaring little children. The great Faces are sacred and should not be ridiculed; and the being they represent might, through the mask, "poison" the child, or "spoil his face" and bring bad luck to the wearer.

THE BIGHEADS

At the mid-winter festival, two women dress two men in buffalo robes, which they bind with ropes of braided corn husks,[8] from which the ears have been successively pulled for consumption; they hand the men wooden corn-pounders and dispatch them about the village. These heralds impersonate the "Uncles" or "Bigheads" who run through the fires

[7] Arthur C. Parker, "Secret Medicine Societies of the Seneca," 1909. Reprinted in New York State Museum, *Museum Bulletin* 163. Albany, 1913, p. 129.

[8] Two men dress them at Newtown.

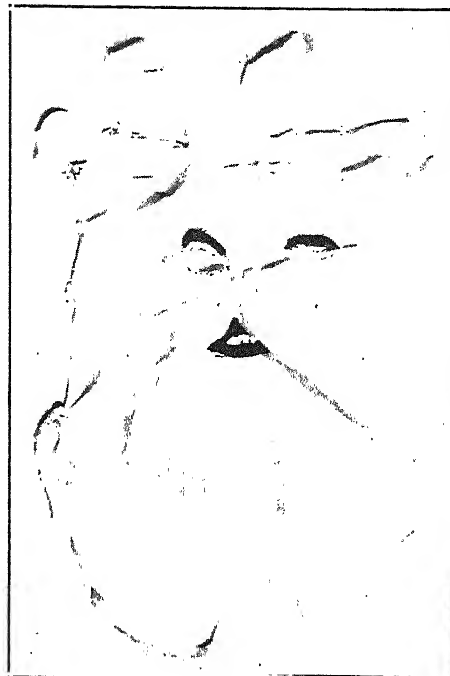
heralding the Feast of Dreams which marks the new year. Their costume symbolizes the union of trophies of the hunt and fruit of the harvest. The Bigheads should not be confused with the wooden False Faces or the Husk Faces, who form two distinct but somewhat linked medicine companies.

The Origin of False Faces

Among the Seneca there are two prevailing types of origin legends for the wooden False Faces. One is a mythical epic belonging to the creation; the other is a human adventure. Both are associated with different classes of beings. In abridged form, here is what Chauncey Johnny-John and Henry Red-Eye heard from their "old folks."

The Struggle for Control of the Earth

Now when our maker was finishing this earth, he went walking around inspecting it and banishing all evil spirits from his premises. He divested the Stone-coats and banished them as harmful to men. He removed the Little Folk's stone shirts and permitted them to remain to help hunters and cure illness. As the creator went on his way westward, on the rim of the world, he met a huge fellow—the head man of all the Faces. The creator asked the stranger, as he had asked the others, whence he came. The stranger replied that he came from the Rocky mountains to the west and that he had been living on this earth since he made it. They argued as to whose earth they traversed and agreed to settle the title by contest. The Creator agreed to call the stranger "headman," should he demonstrate sufficient magic strength to summon a distant mountain toward them. They sat down facing the east with their backs to the west and held their breaths. Now the great False Face shook his giant turtle rattle and the uproar frightened the game animals. He summoned the mountain toward them, but it moved only part way. Now it was the Creator's turn, and he summoned the mountain, which came directly up to them. However, his rival, becoming impatient, suddenly looked around, and the mountain struck his face. The impact broke his nose bridge, and pain distorted his mouth. Now the Creator realized that this fellow had great power. He assigned him the task of driving disease from the earth and assisting the people who were about to travel to and fro hunting. The loser agreed that if humans make portrait masks of him, call him grandfather, make tobacco offerings, and set down a kettle of mush, that they too shall have the power to cure disease by blowing hot ashes. The Creator gave him a place to dwell in the rocky hills to the west near the rim of the earth, and he agreed to come in whichever direction the people summon him.



Fenton Collection.

The mask of Longnose who kidnaps naughty children.

The Good Hunter's Adventure

Later, as humans went about the earth, in the fall men went into the woods hunting. They carried native tobacco and parched corn meal for mush. They were tormented by shy, querulous beings who flitted timidly behind trees with their long hair snapping in the wind. Sometimes, a hunter returned to his camp to find the ashes of his fire strewn about the hearth and the marks of some great, dirty hand where someone had grasped a house post for support as he leaned over and pawed in the fire. The hunter agreed to stay home while his partner went afield. During the morning, a False Face approached cautiously, sledging on one hip, now and then standing erect to gaze about before

proceeding. Going to the hearth, he reached into the ashes and scattered the coals as if seeking something. That night the hunter had a dream in which the False Face requested tobacco and mush. The next day, the hunter set a kettle down for them. The Faces came and taught him their songs and their method of treating patients with hot ashes. In a subsequent dream, they requested him to remember them every year with a feast, saying they are everywhere in the forests, bringing luck to those who remember them.

Another legend from Chauncey Johnny-John tells of a hunter who inadvisedly shot, but failed to kill an old man whom he discovered seated on a log in the forest. The man returned the arrow, instructed the hunter to make one hundred bark bowls, to cook a great kettle of mush, and provide tobacco for a company of one hundred who would appear next day. The surprised hunter fulfilled everything, and when he was ready, Faces of all ages gathered around his fire. The old man, who was their leader, taught him a tobacco invocation and three songs. They showed him how to cure by blowing hot ashes, and presented him with a miniature mask to serve as a model for making larger ones.

Hunters returned home to their villages. They related their strange adventures and revealed their dreams. Sometimes after returning home, they had new dreams and received further instructions. They showed their people how to make masks and they organized a medicine company.

The Classes of Medicine Masks

Rationalizing from the two types of origin legends, the modern Seneca conceive two main classes of False Faces: first, their leader, the great fellow who lived on the rim of the earth, and secondly, his underlings, the common forest people whose faces are against the trees. The great one, called shagodjowéhgo·wa·', is the greatest doctor. He is earth bound and traverses the earth from east to west following the path of the sun. He is tall and carries a great staff, made from a giant pine or shag-bark hickory tree with its branches lopped off to the top. He walks with great strides, bumping his cane and shaking the earth. He carries a huge mud-turtle rattle, and he

OUR UNCLES, THE BIGHEADS.

At the Midwinter Festival, two men are appointed, one from each group of four clans, to impersonate the Bigheads who make three excursions from house to house announcing the New Year ceremonies. Their buffalo robes represent hunting, the corn husk braids symbolize agriculture, and the striped corn pounders signify the return to sedentary village life.

stops at noon to rest and rub his rattle on the giant elm or pine which stand in the center of the earth and from which he derives great strength. His face is red in the morning as he comes from the east, but black in the afternoon as he looks back from the direction of the setting sun. He controls high winds and has a wary eye for pestilences which might destroy the people. He has a song which refers to his power over winds and pestilence. Few have ever seen him. He dances, kicking out his feet and sparring, his thumbs pointed in the air as if he were about to fall over backward. He makes the people imitate him, organizes them in a round dance, and watches the door to see that no one leaves or enters. Masks representing him have long hair. They are painted red or black and portray the broken nose and pain he suffered when the mountain struck his face. A few masks have high bridged noses, and all have protruding lips, which are either distended like two funnels or flattened like two spoons, for blowing ashes.

The second class are the Common Faces, who live everywhere in the forests. They are deformed, either hunchbacked or crippled below the waist. Some carry rattles, made by folding a rind of hickory bark; a few possess turtle rattles, but others have only a stick. They crave mush and beg for tobacco. They have a dance and a song, and they will cure by blowing hot ashes. Masks of this category are ill defined and include a great variety. Frequently new masks make their *début* with the Common Faces; but after they have been worn in many rituals, borrowed and passed through the hands of several owners, they will have accumulated several bags of tobacco offerings, attained an antique color, and achieved sufficient prestige to graduate into the class of great doctor masks where their sanctity is preserved by reputation.

Three Societies Employ Masks

Among the Seneca, three distinct medicine societies employ masks. They perform their rituals in public or privately. The False Face Company, who wear the wooden masks, include both the orders of medicine masks who have three distinct rituals. Their public rituals are the spring and autumn exorcism of disease from the settlements and cures which are sometimes sponsored in the longhouse

OUR MIGHTY PROTECTOR TRAVERSES THE EARTH.

An Allegheny Seneca employs a blanket as a headthrow, wears his father's mask and carries a turtle rattle to impersonate Shagodjowéhgo·wa·' whose heavy tread shakes the earth.

during the mid-winter festival. However, the public appearance of the Beggars and Thieves, during several nights of the mid-winter ceremonies, are merely a motley group of boys who sometimes "take sick" afterward and thereby gain admittance to the society. The second ritual belongs to the Common Faces, who enter a house and dance. The Common Faces may be followed by the great, world rim Faces, whose ritual is the Door-keeper's Dance. The Society of Faces is the body of people who have been cured by the masked company. The separate society of Husk Faces appears publicly two nights at the mid-winter festival. They have their own invocations, songs and a curing dance. Membership is gained by a dream or cure, but non-members join in their public dances, dancing at the end of the line.[9] Frequently, at Allegany two special Husk Faces appear as door-keepers for the Common Faces at private curing rites and as heralds and longhouse police during public rituals. Among the Canadian Iroquois, masked societies seem more highly specialized, but at Allegany and Tonawanda their functions are less clearly defined. At Newtown, on Cattaraugus reserve, the Society of Mystic Animale (hadi·'do·s) possess certain "secret masks" of which one has no eye holes, but at Coldspring on Allegany Reservation certain black or white Faces, which are also used as medicine masks by the Society of Faces, appear in one ritual of the Society of Mystic Animals and juggle hot stones or hot ashes while curing the patient.

Membership

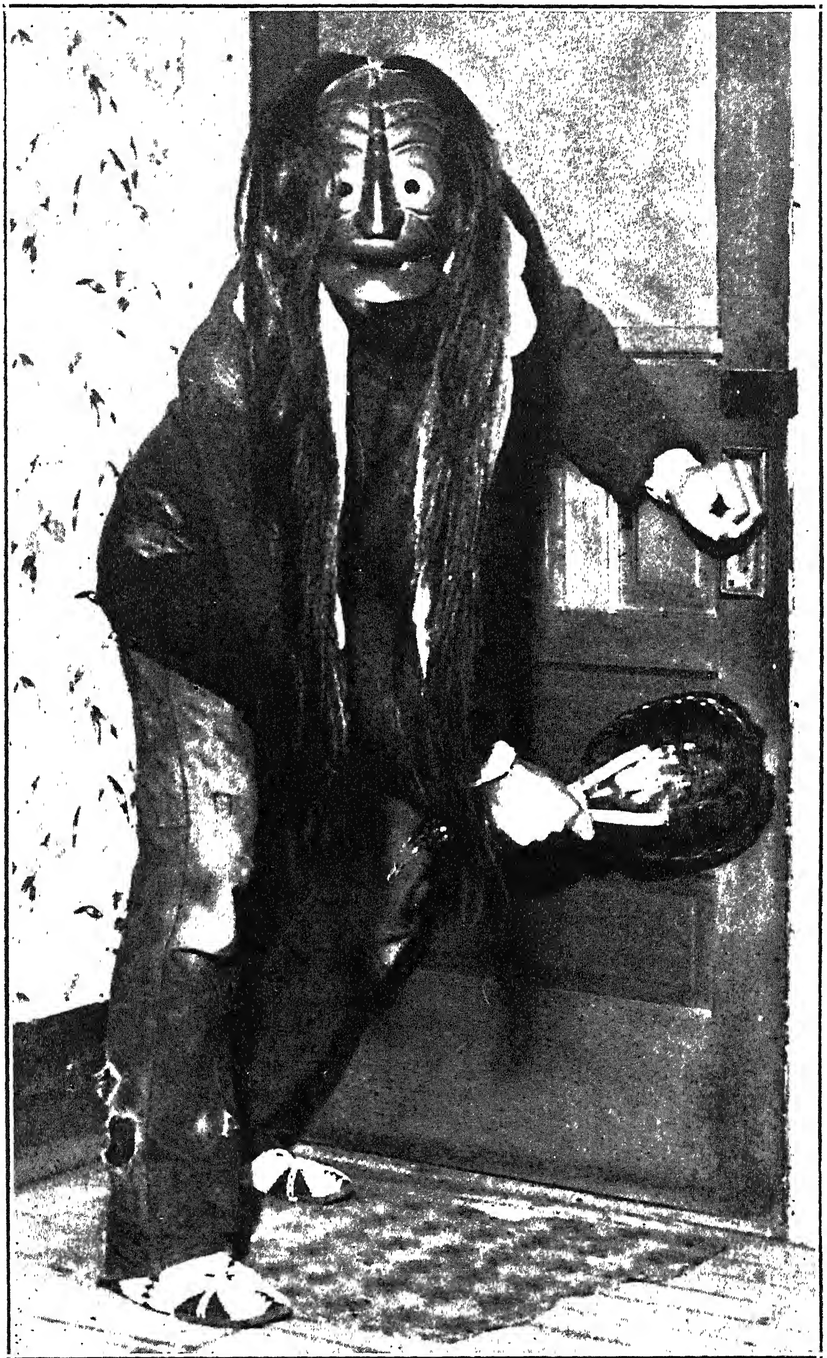
A Seneca Indian joins a particular medicine society after a dream or following a sickness because a clairvoyant has prescribed the ritual of that society for his cure. He automatically joins all the societies, and is afterward duty bound to sponsor any combination of rituals that have assisted his recovery. Thus the Society of Faces includes those who have been cured by the False Face Company. Membership in the several orders of the society, or participation in the rituals of the masked company depend on the individual's personal history. The masked company are men wearing masks of the orders which cured them, but both men and women sponsor the rituals and belong to the orders who have accepted them for membership in the society by making them sick. Two head women, one from each moiety of four clans, are responsible for certain equipment and manage the rituals. Members of both sexes attend. A member should put up a feast every year for the orders which have helped him. He calls in the head woman of the opposite moiety to conduct the ritual. His membership ceases rarely, when he dreams he has been outcast. Then he knows he is no longer a member.

The False Face Sickness

Symptoms of the False Face sickness are ailments of the head, shoulders and joints. They cause and cure swelling of the face, toothache, inflammation of the eyes, nose bleeding, sore chin and earache.[10] At Tonawanda, red spots on the patient's face are False Face symptoms. This calls for the red Faces, who should dance in the morning before sunrise. Black spots require the use of black masks at night. Imaginary hair, lying on the patient's face, indicated by her attempts to brush it aside, is a False Face symptom. The patient complains to her old people. They consult a clairvoyant, who prescribes a False Face ceremony.

[9] A. C. Parker, "Secret Medicine Societies of the Seneca," 1909. Reprinted in New York State Museum, *Museum Bulletin* 163. Albany, 1913, p. 129.

[10] A. A. Goldenweiser, "Field Notes circa 1912." Vol. 12, p. 41; Lewis H. Morgan, "League of the Iroquois," Vol. I, pp. 157–160. N. Y., 1901.



THE DOORKEEPER.

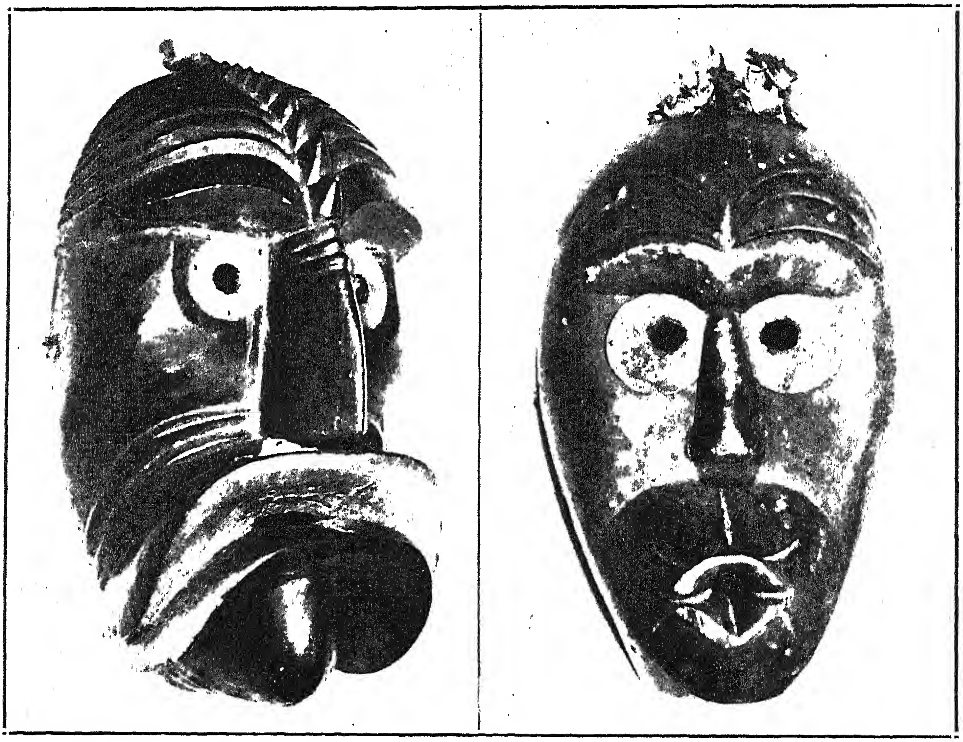
SHAGODJOWÉHGO·WA·' PERMITS NO ONE TO ENTER OR LEAVE DURING HIS RITUAL. THE MASK, FROM CATTARAUGUS RESERVATION, IS THE PROPERTY OF THE ROCHESTER MUSEUM OF ARTS AND SCIENCES.

To ridicule the masks or any of their ceremonies is inviting sickness or misfortune.

A peculiar form of hysterical possession formerly occurred among women at Tonawanda. An informant states that it was confined to certain nervous women who became possessed of the False Face spirits whenever the masked men appeared.[11] On hearing the rumpus of whining and rattles, which marks their approach, one woman would fall into spasms, imitate their cry and crawl toward the fire, and, unless she was restrained, plunge her hands into the glowing embers and scatter the fire as if she were a False Face hunting tobacco. Some one always grabbed her, while another burnt tobacco, imploring the masked men to cure her. The ritual usually restored her normal composure. Other women became possessed of the tutelaries of the Bear or Buffalo societies. My informant used to think women became possessed to show off. Some of these women were clairvoyants. Another informant remembers a man who became possessed,[12] thirty years ago at Newtown, for resisting a Door-keeper. When the masked ritual conductor nudged him with his rattle, he obstinately refused to join the round dance. They struggled

[11] Peter W. Doctor.

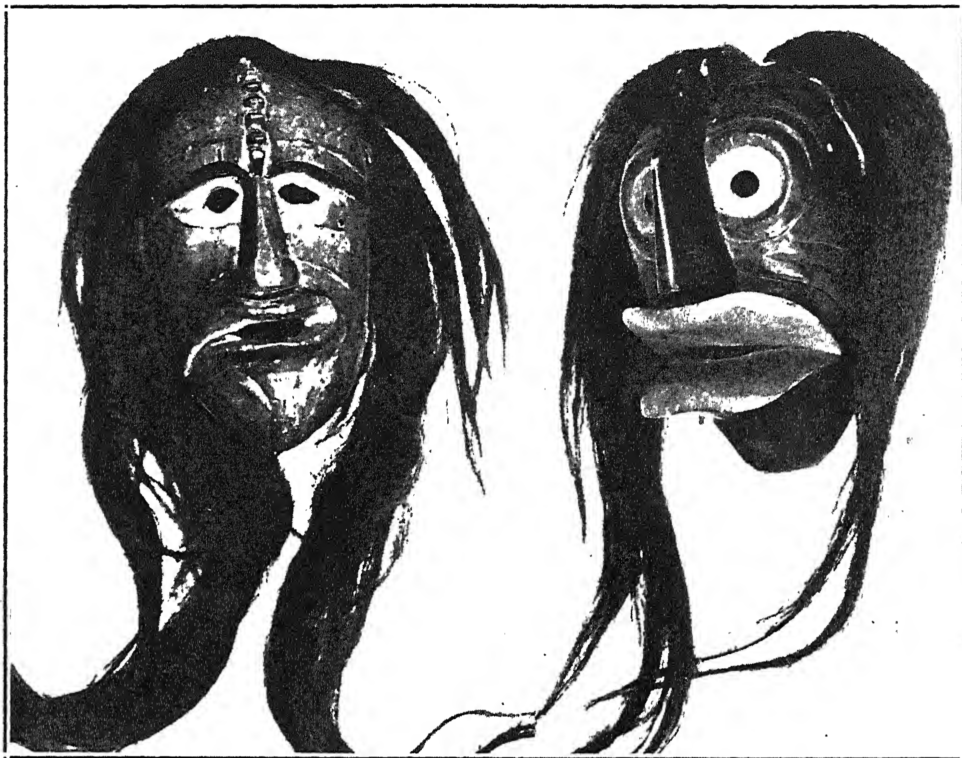
[12] Jesse J. Cornplanter.



Fenton Collection.

CARVING HAS IMPROVED WITH NEW TOOLS.

(*Left*). An unfinished black Door-keeper mask by Clarence White of Coldspring, 1923. Lacking long hair, this face might appear as a Beggar. (*Right*). The Whistling Face, a Beggar, that suggeste a mask in use among the Delaware. The tobacco bags at the forehead attest its long use.



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DOOR-KEEPER MASKS ARE RED OR BLACK.

(*Left*). AMOS SNOW'S MASK, PERIOD OF ABOUT 1850, PORTRAYS "THE BROKEN NOSE AND THE CROOKED MOUTH WHERE THE MOUNTAIN STRUCK HIS FACE." (*Right*). JONAS SNOW'S MASK, MADE ABOUT 1924 AT COLDSPRING, IS A FINE EXAMPLE OF MODERN CARVING AND THE DOOR-KEEPER FACE WITH PROTRUDING LIPS.

and the man, overcome with fear, fell into a spasm and cried like a False Face. They had to blow ashes on him. Afterward, the man did not remember his behavior. In all cases, the form of the hysteria was prescribed by the culture.[13]

THE MASK AND RATTLE

Men belonging to the Society of Faces usually own a bundle containing a turtle rattle and one or more masks decorated with bags of sacred tobacco. When not being used, the mask is laid away, face down with its hair wreathed around the face and the turtle shell placed in the hollow at the back of the mask; and the whole is wrapped in the cloth head cover. Sometimes, unwrapped masks are hung upstairs, but facing the wall. A mask hung facing out should be covered, lest some frightened persons become possessed and join the society. One must be careful of them. If a mask falls, the owner burns a tobacco offering and ties a little bundle of sacred tobacco at the ear or forehead. Whenever he dreams about the Face, he will rise and repeat the ritual. Every man has a package of

[13] The Feast of Fools, described by the Jesuits, has evolved from a random series of hysterical dream fulfilments to an organized midwinter festival by a gradual standardization of forms differing according to locality.

A MEDICINE MASK AT COLDSPRING.
THIS BEGGAR MASK HAS, THROUGH LONG ASSOCIATION WITH CURING, ACCUMULATED SEVERAL BUNDLES OF SACRED TOBACCO AND NOW BELONGS TO THE CLASS OF DOCTOR MASKS.

tobacco on his mask which he removes when he sells it to white people. He burns tobacco, telling the mask that it is going away. He asks it not to return and harm him or the new owner. Everyone belonging to the society may use any one else's face. A new owner will add a package of tobacco to a mask, and if he purchases one already having several medicine bundles attached, he adds his own; but a maker does not tie tobacco on a mask unless he intends to keep and use it. Sometimes the masks become hungry and the owners rub their lips with mush and anoint their faces with sunflower oil, which after many years imparts a rich luster. A man, having no children, may request that a mask be buried with him.

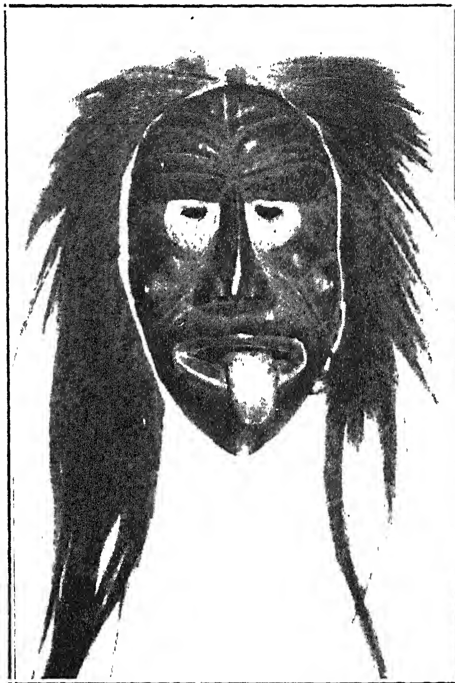
Unless the new member inherits an old mask, he must carve one or enlist the services of a carver. They say at Tonawanda that "Softer woods are best for carving masks. Basswood has the prestige of tradition, but other soft woods like willow and cucumber . . . are also used. Anciently, a man went into the forest to carve his masks. He carried native tobacco and sought a living basswood tree. Now he committed the tobacco to the burning embers, a pinch at a time, addressing his prayer to the tree and the beings whom the False Faces represent. Then he carved the face on the living tree, and having roughed it out, he notched the tree with an axe above the forehead and below the chin and cleaved away his sculpture in a solid block. It is said that the carving never broke because one had put tobacco and asked the tree for its life. Nor did the tree die. Within four years, the scar healed over. He took home his block, covered it and worked on it at his leisure. When the features were finished, he hollowed out the inside (with a bent, farrier's knife), and perforated the eyes, nose and mouth. He encircled the eyes with metal, for the Great False Face's eyes are bright. Then he painted it. If he had sought his tree in the morning, he painted the mask red; but if he found the tree and commenced carving after noon, the mask would be black."[14] This color symbolism originates with the theory of morning and afternoon appearance of the giant, world rim resident. During his daily, westward journey following the path of the sun, his

[14] Cephas Hill and William N. Fenton, "Reviving Indian Arts Among the Senecas," "Indians at Work," Vol. II, Number 21, pp. 13–15. Office of Indian Affairs, Washington, D. C., June 15, 1935, p. 14.

face would appear red in the morning and dark in the afternoon when the sun is behind him. For the long hair which falls on either side to his knees, the mask-maker attaches to the forehead horsetails, tanned with deer brains.

Ritual Equipment

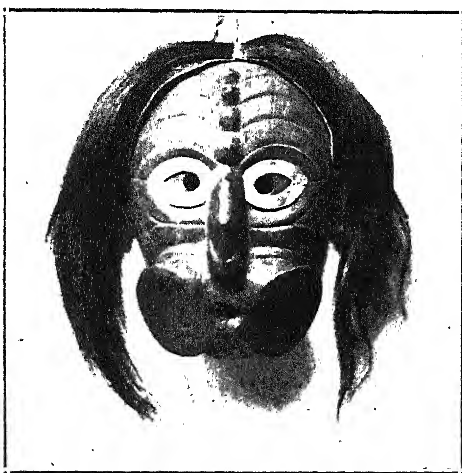
The False Face Company carry wooden staves and employ three instruments: the typical mud-turtle rattle, a folded bark rattle or a billet of wood. On late spring evenings, before summer heat peels the turtle's shell, Indians watch for turtles about the ponds and creeks. In the evening one may meet an Indian bearing a burlap sack containing a turtle, or he carries it by the tail; he is bound to the house of a friend who "can fix it" for a rattle. The rattle maker cuts off the turtle's tail or severs the jugular vein and hangs it to drain. Later, he eviscerates and cures it. He sews up the apertures left by removing the rear limbs and inserts a handful of cherry pits. He stretches the neck over a pine stick which extends from inside the shell to the base of the skull where it is notched. He sews the front rents. Cutting three hickory splints, he inserts one in the sternum, cutting it off under the jaw, and he inserts two lateral splints in the back of the shell, terminating them on top of the head. He binds the splints to the neck with basswood fiber, a withe of inner elm bark, or rawhide, commencing at the shell and whipping toward the head. A ten-inch rattle is best for singing, but the mammoth turtle rattles lend awe to the door-keepers at curing rites and small turtle rattles furnish comedy for little boys playing beggars.



Fenton Collection.

A MEDICINE FACE FROM GRAND RIVER.

Canadian masks are massive and heavy and longer than the average human face. A Coldspring Seneca bought this mask of a Grand River Seneca and brought it home.

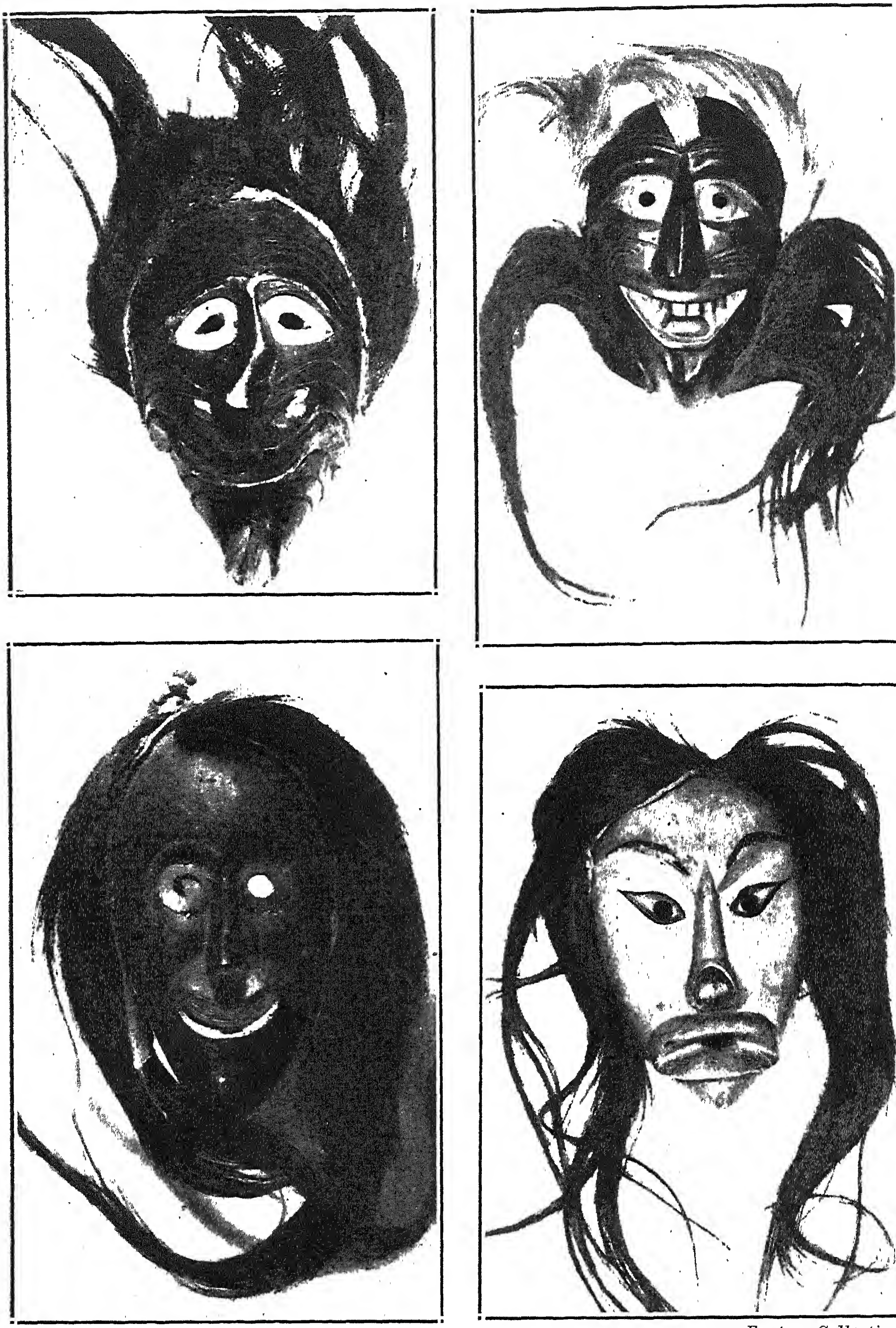


Buffalo Historical Society.

SPOON-LIPPED DOOR-KEEPER MASK.

The spoon-lipped door-keeper is characteristic of Cattaraugus. The mask illustrated has ears perforated for earrings, silver eyes and the ridge of spines above the nose called "Turtle-tail."

For the bark rattles, a cylinder of



Fenton Collection.

THE COMMON FACES INCLUDE A GREAT VARIETY.

(*Upper left*). This mask, which Chauncey Johnny John made about 1900 for his wife's brother, has gone through many curing rituals. (*Upper right*). Beggar masks usually have standing hair, but this one also has a beard and a broken nose like the ancient World-rim-dweller. (*Lower left*). A Happy Face, a Beggar mask made at Coldspring about 1920, credited with great healing power. (*Lower right*). The Chinaman Beggar mask.

green hickory bark is slit longitudinally and peeled around the tree. The maker spreads it at the middle by inserting his thumbs and folds it end to end, placing one curled end inside the other. A few cherry pits, pebbles or kernels of corn provide the necessary percussion. He plugs the open end with a corn cob and lashes it with a bark withe. A man will make a dozen on a summer afternoon and toss them overhead in the loft to dry.

At next mid-winter festival, a band of outlandishly dressed little boys wearing beggar masks may visit him soliciting or pilfering food and tobacco for a feast. He will reward them, and then, reaching overhead, distribute his rattles to those poor youngsters who were unable to locate turtle rattles and carry sticks of kindling. Perhaps he has no children of his own. He will sing for them and they will dance and depart.

A rattle borrowed from a dancer or a stick of wood is good enough to beat time for the dances. But despite the Indians' ingenuity to make shift of anything at hand, the False Face Company sometimes possess dance-tempo beaters. They range in design from wooden cudgels to elaborately carved wooden turtles that have been hollowed to house noisy pebbles. These wooden replicas of the genuine turtle rattles exemplify the transfer to an artistic medium of a design originating with a structural invention.

Miniature Masks

Boys sometimes learn by carving miniature masks. The mask may make the owner ill and then he joins the society. Masquettes are also charms to protect dwellings against witchcraft, or they hang on larger masks. A man may carve one in response to a dream and carry it for good luck. At Cattaraugus, the matron of the society carries a striped pole on which a tobacco basket, a small wooden face, a tiny Husk Face and a diminutive mud-turtle-rattle hang near the top. This is her staff of office when she leads the masked company from house to house exorcising plagues.

Spring and Autumn House Cleaning

In the spring and fall, when sickness lingers in the settlements, a great company, wearing both classes of medicine masks, go through the houses frightening disease spirits. At Coldspring, two groups start at opposite sides of the settlement. They are preceded by Husk Face runners. Members take down their masks and rattles and join the procession as it passes. The masked exter-

Rochester Museum of Arts and Sciences.

THE CARVER.

The Carver, Harrison Ground of Tonawanda, outlines the features of the face before hollowing the back of the mask.

THE COMMON FACES OF THE FORESTS ARE CRIPPLES.

MASKS OF THE DOORKEEPER TYPE FREQUENTLY APPEAR TOGETHER WITH THE COMMON FACES, AND SINCE THE RITUAL PRESCRIBES A CRAWLING POSTURE FOR COMMON FACES AND ERECT STATURE FOR DOORKEEPERS, THE BEARING AND GESTURES OF THE ACTOR ARE MORE IMPORTANT THAN THE TYPE OF MASK HE WEARS.

Rochester Museum of Arts and Sciences.

CROOKED FACE ENTERS CRAWLING LOOKING FOR TOBACCO.

THIS BEGGAR MASK, WORN BY DENISON MOSES, WAS CARVED BY ELON WEBSTER OF TONAWANDA ON A WPA INDIAN ARTS AND CRAFTS PROJECT SPONSORED BY THE ROCHESTER MUSEUM OF ARTS AND SCIENCES. THE MOCCASINS REPRESENT A WESTERN BORROWING.

minators frequently strip to the waist and go armed with rattles to scare the spirit of sickness and carry pine boughs to brush away malefic influences. A believer is said to suffer no injury from plunging his bare hands into the fire nor become sick from exposure while traveling in cold weather. One winter at Allegany the company afforded a wild spectacle as they sped up the valley road in open Fords with their hair whipping in the chill winds; they grated their rattles on the car body and uttered their terrifying cries whenever they swerved to pass a stranger. Approaching houses occupied by members of the society, an unmasked leader sings:

A long voice, A long voice
yowige yowige wige

and again on entering the longhouse:

It might happen, It might happen
ha i ge ha i
From the mighty Shagodjowch
ha i ge he i
I shall derive good luck
ha i ge he i.

He hopes that the great one dwelling on the rim of the earth will confer his power on the masked company and prevent high winds from leveling the settlement. They scour the exterior of the house and, crawling through the door, visit every room. They sweep beneath the beds and peer into every nook and corner for disease spirits. They haul the sick out of bed and sometimes commit indignities on lazy people. If some one has set a kettle down for them, their leader will burn tobacco, and ask the masked company to blow ashes on the patient. Their only fee is native tobacco, which their guide collects in a twined, husk basket. Once at Newtown, a leader was about to gather his company of exterminators and depart for another house when one turned up missing. They heard a most terrifying racket in the loft. They ascended to discover him violently shaking an old straw bed tick-

ing, from which bedbugs were fleeing by the score. This fellow, now an old man, possessed of an extraordinary sense of the ridiculous, was shaking his rattle and crying in the most orthodox manner. It is a good example of the frivolity which may pervade an otherwise serious ritual.

Meanwhile, the two matrons brew a purgative at the village cook-house. At Newtown and Tonawanda, the sole ingredient is parched, white sunflower seeds, which are steeped for the medicine, but at Allegany they add "man-root" (*Ipomoea pandurata*), which must be found growing erect like a living person.

The community assembles at the long-house. An appointed speaker returns thanks to all the spirit-forces. At Cold-spring, Husk Face runners and the marching song signify the approach of the combined company. Bursting into the room, the False Faces crawl toward the fire. Each matron entrusts a pail of medicine to one of them whom she designates "water waiter" for her moiety. Lest they scatter the fire about the room, an appointed priest makes an invocation, burning the tobacco that was levied at the houses. He implores them to protect the people against epidemics and tornadoes.

TOBACCO INVOCATION

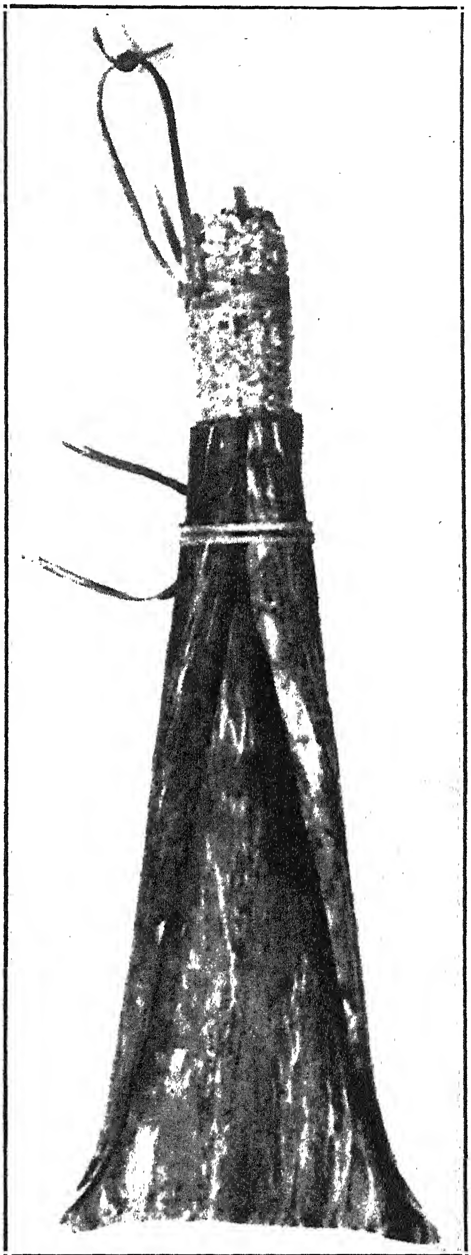
Partake of this sacred tobacco, O mighty shagodjoweh, you who live at the rim of the earth, who stand towering, you who travel everywhere on the earth caring for the people.

And you too, whose faces are against the trees in the forests, whom we call the company of faces; You also receive tobacco.

And you Husk Faces partake of the tobacco. For you have been continually associated with the False Faces. You too have done your duty.

Partake of this tobacco together. Every one here believes that you have chosen him for your society.

So now your mud-turtle rattle receives tobacco. (Here they scrape their rattles on the floor).



Fenton Collection.

A FOLDED HICKORY BARK RATTLE.

So now then another thing merits tobacco, the very place where you rub your rattle, the giant elm tree standing on the center of the earth. (Again they approve.)

MAKING A TURTLE RATTLE.

JONAS SNOW BINDS THREE HICKORY SPLINTS TO THE TURTLE'S NECK WITH RAWHIDE LASHING.

And now another thing receives tobacco, your staff, a tall pine with the branches lopped off to the top.

So presently you will stand up (they crawl in) and help your grandchildren, since they have fulfilled your desires. Fittingly, they have set down a full kettle of mush for you. It is greased with bear fat. Now another thing is fulfilled: on top there are strips of fried meat as large as your feet. (Here the False Faces roll in ecstasy on their backs, grasping their feet, peering at them, and attempting to put them in their mouths). Besides, a brimming kettle of hulled corn soup rests here.

Now it is up to you. Arise and help your grandchildren. They have fulfilled everything that you requested should be done here. In my opinion we have these ashes here for you to use. Arise and make medicine. That's all.

Here the priest summons those who wish to be cured to come forward and stand near the fire to receive the administrations of the False Faces.

The masked waiters pass the medicine water. Every one drinks all he can. Two Husk Faces watch the doors to insure that no one leaves or enters during the imbibing. However, they can sometimes be bribed with a pinch of tobacco.

There are dances for each class of Faces. An appointed singer straddles a bench, and borrowing a rattle, sings for the Common Faces alone. They stand up and dance and apply hot ashes to any patients whose dreams have required that they be cured on this occasion. Frequently, little boys who are wearing masks have to be held up by their elders in order to blow ashes on the patients' heads. Sometimes, a clever little fellow will puff the ashes at the patient from his upturned hand. At Tonawanda, the masked dancers cure each other. A matron distributes tobacco and they depart with their kettle of mush.

Next the Husk Faces perform, receive popcorn and bound out of the room.

The second part of the ritual, named "They place one foot ahead of the other" for one of its component dances, includes the Dance of the Door-keepers. The song commences. Two men, who are appointed from opposite moieties, appear wearing the medicine masks representing the great world rim beings. They dance with the matrons, each facing the woman of the other moiety. A couple dances in unison, hopping on the left foot while bending the right knee and then kicking out the right foot. At the same time they spar at each other with the extended left hand, pointing the thumb upward. The turtle rattles dangle by the loop on the handle. Now the matrons pair the men and women in couples who dance imitating the False Faces. They spar at each other and a bold woman will somtimes back a bashful man from the floor. A door-keeper looks inside once during each song.

Then they return and compel every one inside to join a round dance, from which the ritual takes its name, since a dancer lifts his foot, bumps his heel and sets it down again ahead of the other. One door-keeper directs the dance, while his cousin watches the door to see that no one escapes the ritual.

The member who wears the mask to impersonate the door-keeper is supposed to know the members of the society. You can pick out the members. They look scared. They look at you hard, or they pretend to be busy about some other business of their own. You can discern them through the mask. If any are reluctant to join, you have the power to force them, a strength against which they dare not resist. Sometimes fights occur. If one is not able, his partner, the other door-keeper, will help him. Members *must* dance.[15] Those who resist become possessed.[16]

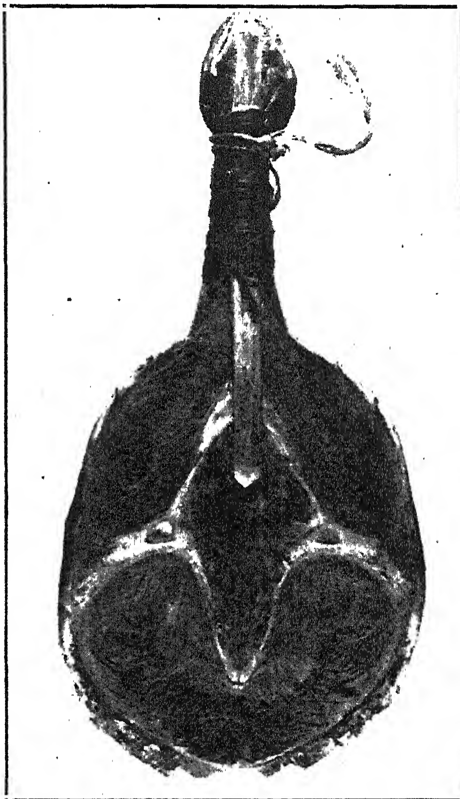
The round dance continues until certain songs request them to blow ashes. They repeat their square dance with the two matrons, blow ashes on their heads, receive tobacco and depart. The feast is hulled corn soup.

Although I have outlined the great public ritual, the same general pattern holds for private medicinal rites. The only difference is that the priest mentions the parson's name in the tobacco invocation. Then the complexity of the ritual depends on the number of orders to which the patient belong.

The simpler ceremony of the Common Faces alone has been vividly treated by Ernest Smith, a Seneca Indian artist of the Tonawanda reservation, in the accompanying painting.

The Blowing Ashes Rite

The setting is the interior of a bark house, common among the Iroquois a few generations ago, and the time is presumably an evening of the Mid-winter Festival. In response to a dream, the host has prepared a kettle of mush, or False Face pudding, and summoned the False Faces. The announcer, who is painted sitting on the bench, has returned thanks to all the Spirit-forces, explained the purpose of the feast, and invoked the Faces-of-the-forests with burning tobacco. They have entered. The singer straddles the bench to beat out the tempo for their dance, which they energetically commence, scattering ashes everywhere. They hasten to finish curing the patient, their host who stands before the fire, since they crave tobacco and hunger for the kettle of mush which he has set down



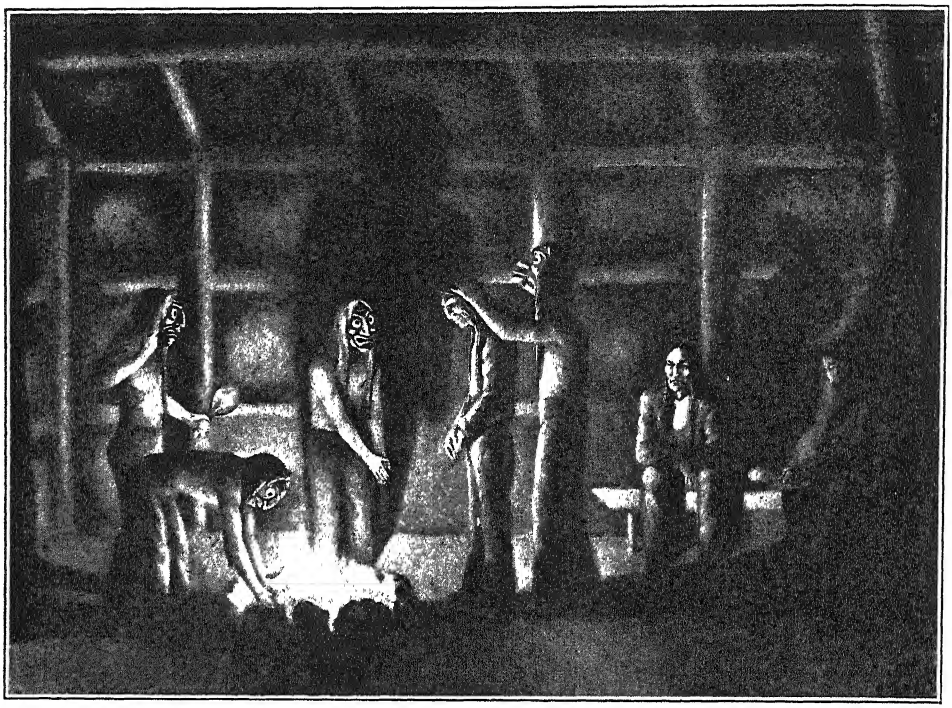
Fenton Collection.

A MUD-TURTLE RATTLE.

for them. A tall, red-faced fellow vigorously rubs the patient's scalp before blowing the hot ashes into the seat of the pain. A dark one moans anxiously while rubbing hot ashes between his palms prior to pouncing on his victim's shoulder and pumping his arm. Across the fire, a red face stoops to scoop live coals, while another impatiently shakes a turtle rattle.

[15] Chief Henan Scrogg of the Snipe clan at Tonawanda.

[16] Jesse Cornplanter.



THE CURING RITES OF THE COMMON FALSE FACES.
PAINTING BY ERNIE SMITH, SENECA INDIAN ARTIST OF THE TONAWANDA RESERVATION.

They are naked above the waist, but wearing the masks is said to protect their bodies from cold and their hands from the burning embers.

Although the real Faces are seldom seen now, modern Iroquois, especially little children, fear them. A being which has the power to control disease, who can also cause the same ailment which he cures, is a subject for concern. The degree to which the False Faces dominate the lives of the Iroquois is well illustrated in the testimony of a sophisticated woman of Shawnee and Cayuga parentage whom Dr. Margaret Mead met among the Omaha. The informant had long since removed from her own tribesmen, but her childhood impression remained.

I remember how scared I was of the False Faces; I didn't know what they were. They are to scare away disease. They used to come into the house and up the stairs and I used to hide away under the covers. They even crawled under the bed and they made that awful sound. When I was bad my mother used to say the False Faces would get me. Once, I must have been only four or five, because I was very little when I left Canada, but I remember it so well that when I think of it I can hear that cry now, and I was going along a road from my grandfather's; it was a straight road and I couldn't lose my way, but it was almost dark, and I had to pass through some timber and I heard that cry and that rattle. I ran like a flash of lightning and I can hear it yet.

THE TARPON IN THE PANAMA CANAL[1]

By Dr. SAMUEL F. HILDEBRAND
ICHTHYOLOGIST, U. S. BUREAU OF FISHERIES

THE tarpon (*Tarpon atlanticus*) long has held a place of high esteem among anglers and is considered by many to be the world's gamest fish. Whether caught on a hook or surrounded by a net it wages a terrific fight for freedom. The sportsman, when properly equipped, generally delights in hooking the tarpon. The net fisherman, on the other hand, almost hates to find them in his net, for the large, powerful fish (the largest one reported to date being 8 feet, 2 inches long) too often "run" through the net, leaving large gaping holes. Furthermore, the fishermen sometimes are endangered by the large fish, for if they do not succeed in breaking through the net the fish generally leap high into the air, occasionally striking a fisherman in their efforts to free themselves. Commercially the tarpon has little or no value, as in most localities the fish is not marketable. In Panama the natives and particularly the West Indian immigrants, however, are very fond of tarpon, which is known to them as "sabilo real," *i.e.,* king shad. Some fishing is done on a commercial basis and tarpons frequently are seen in the Colon market.

Although the tarpon has been sought far and wide by anglers, and to some extent by naturalists, throughout its range, which extends from Cape Cod to Brazil and through the West Indies, much of its life history remains a mystery. It is not known to the present day where its spawning grounds are. Nor have the manner of spawning, the spawned eggs and the early larvae been discovered.[2]

It had long been supposed that the tarpon, like some of its near relatives, passed through a leptocephalus stage similar to the eel. In this larval stage the fish is very strongly compressed, ribbon-shaped and almost transparent; certainly bearing no resemblance to the parents. A full grown leptocephalus, of those species that have been studied, is considerably longer, though not greater in bulk than the newly transformed young. For example, the leptocephalus of *Elops saurus,* known as the bonyfish in Panama, a relative of the tarpon, reaches a length of fully 60 mm, but during transformation it is reduced in length to about 20 mm. That the tarpon does pass through a leptocephalus stage was proven a few years ago, when the author of the present article described in *Copeia* (April, 1934) a young tarpon 20 mm long, which was in the transition stage.

This postlarval tarpon was taken in an estuary at Beaufort, N. C. It does not necessarily follow, however, that tarpons spawn in that vicinity. We need only to remember that both the American and European fresh-water eels spawn in the ocean between Bermuda and the West Indies, and that the European eel travels across the Atlantic in the leptocephalus stage and then transforms and enters fresh water, and the American eel similarly migrates to our shores before it transforms. Therefore, the postlarval tarpon taken at Beaufort may have been hatched far from the place of capture.

Young tarpons, of about 2 inches and

[1] Published by permission of the U. S. Commissioner of Fisheries.

[2] For the most complete account of the tarpon published the reader is referred to a book entitled "The Tarpon," by Louis L. Babcock, 4th ed., 1936, privately published.

upward in length, have been found by investigators in shallow stagnant brackish water pools at various places, as on Sanibel Island (Fla.), Andros Island (Bahamas), Puerto Rico and Haiti. However, these young were all fully past the leptocephalus stage.

It has been known a long time that adult tarpons inhabit Lake Nicaragua, a body of fresh water a hundred feet above sea level. Recently I. W. Miller (*Field and Stream*, May, 1936) reported more or less regular fishing for tarpon in the Rio Frio, which empties into Lake Nicaragua. The Rio San Juan, which is the outlet of this lake, has falls, the height of which is unknown to the writer. The late Dr. Seth E. Meek (Publication Field Mus., Zool. Ser., VII, 1907), who investigated the fishes of the lake, stated "It is hardly probable that they (tarpon and some other marine forms) have come up over the falls at the head of the Rio San Juan in late years." Dr. Meek, therefore, assumed that the tarpons were landlocked. However, no young tarpons seem to have been found in the lake.

Concerning breeding it can be stated only that tarpons with large roe have been taken from time to time. Such fish have been captured by sportsmen and investigators in June at Boca Grande, Fla.; and in March, April and May at Sanibel Island, Fla. Though there has been some conjecture that these fish spawn in the general vicinity where taken, the fact is that no one knows definitely where the reproductive activities take place. Presumably in the latitude of southern Florida spawning takes place during the spring and possibly summer.

It is evident from the foregoing remarks that the life history of the tarpon was still largely unknown. Therefore, the writer was eager to add something to the known facts of its life history while making an investigation of the fishes of the Panama Canal during the early part of 1935. He was stimulated, further, in devoting special attention to the tarpon by the claim of local residents that both adult and young tarpons were common in Gatun Lake, a strictly fresh body of water. The study was expected to shed some light, also, on the moot question of the use of the locks as a passageway by the tarpons and possibly other fishes. The time for the last mentioned study was particularly auspicious, as the Gatun Locks were dewatered for overhauling during the writer's visit.

The Investigation

The investigation was conducted principally along the following lines: (a) Local anglers were interviewed concerning the occurrence of the tarpon in the waters of the Canal Zone, particularly in regard to their occurrence in Gatun and Miraflores Lakes. (b) A search, principally for larvae and small tarpons, was made in Gatun and Miraflores Lakes and their arms and inlets. (c) Specimens of tarpon were secured and examined for the state of development of the gonads while the Gatun Locks were being dewatered.

It was definitely asserted by several anglers that adult tarpons are year-round residents in the strictly fresh water of Gatun Lake. A few native fishermen, operating principally on the upper part of the lake, in the vicinity of the entrance of the Chagres River, where the fish appear to be most numerous, angle for the tarpon more or less on a commercial basis. Heavy tackle, like that employed for catching sharks, is used.

One fisherman who catches tarpons to sell has built a board walk to deep water at the upper end of Gatun Lake on one of the banks of what formerly was the Chagres River. At the end of the little pier he has rigged a large pole about 25 feet or so in length, which tapers from about 4 to 5 inches at the base to about 2 inches at the small end. The pole is set at an angle of about 40 degrees to the

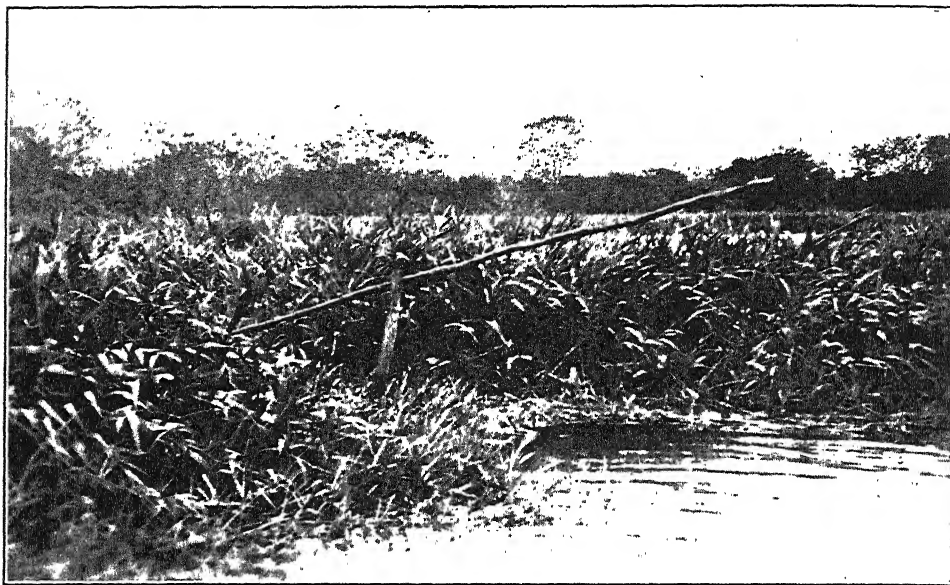
Courtesy William Ackerman

THE TARPON, *TARPON ATLANTICUS*

water and is supported near midlength by a post. The line with the baited hook is attached to the pole. When a large fish (tarpon) takes the hook the movement of the pole can be seen from a distance. By the use of this device the fisherman may stay in a cool shady place, conversing with friends, or possibly engage in other work, until the pole begins to sway.

The description of the native's method of fishing given in the foregoing paragraph is offered, aside from the interest in its uniqueness, to show that the tarpon is sufficiently numerous in the upper part of Gatun Lake to induce a fisherman to go to some expense and trouble to equip himself for the fishery. Others presumably fish just as much as the man who has the boompole, but in a less pretentious way. Americans, of course, fish for sport only. So far as could be learned, tarpons are about equally numerous throughout the year and the sport or fishery is not limited to any particular season.

The writer did not angle for tarpons in Gatun Lake; nor did he see any taken



Courtesy Dr. Herbert C. Clark

BOOMPOLE USED BY NATIVE TARPON FISHERMAN

ON UPPER PART OF GATUN LAKE. A LINE WITH BAITED HOOK IS ATTACHED TO THE POLE.

by others during his visits. However, he did see several large fish "break water" and partly show themselves above the surface, which unmistakably were tarpons.

The more or less regular occurrence of the tarpon in Miraflores Lake (the small fresh to brackish body of water situated on the Pacific slope of the Canal Zone between the Pedro Miguel and Miraflores Locks) was reported by such reliable informants as Mr. R. A. Cauthers, chief of the maintenance office at Pedro Miguel, and by Dr. Herbert C. Clark, director of the Gorgas Memorial Laboratory, who maintains a veterinarian station on the lake. The writer did not see this fish caught in the lake, though he saw a very large fish break water which quite certainly was a tarpon.

It was stated earlier in this article that the writer was informed by several natives of the presence of young tarpons in Gatun Lake. On one of the collecting trips one of the men who claimed that many young tarpons were present in the lake was with the collecting party. We had not been working long when this man called excitedly that we had captured a young "sabilo real." However, this "sabilo real" proved to be an adult silverside, *Menidia chagresi*, about 3½ inches long. Later many more silversides were secured and preserved. These fish were shown to two other natives, who had stated that young tarpons were common in Gatun Lake, both immediately exclaimed "sabilo real." It was evident that the men had mistaken silversides for young tarpons. The search for young fish, however, was continued. Collections were made in many different sections of both Gatun and Miraflores Lakes and adjacent streams, but no young tarpons were found.

The investigator was present to examine the stranded fish during the dewatering of the east side of Gatun Locks, from February 20 to 24, 1935 (the other side having been drained in January, before his arrival in Panama). Several large tarpons (exact number un-

known) were stranded in the upper chamber, which of course was drained first. Only one specimen was secured for examination, the rest having been taken away by the Negro laborers before the writer could get to them. After this experience the superintendent of the locks forbade the men to remove a single fish until the investigator gave permission.

The middle chamber contained eight large tarpons, ranging in length from 3 feet, 3 inches, to 6 feet, 8 inches. The lowest chamber contained none.

It seems of interest to state here that the west side of the locks, dewatered in January, according to Mr. H. M. Thomas, assistant superintendent of the Gatun Locks, contained very few fish and no tarpons, in contrast with a comparatively large variety of species and great quantities of the "bonyfish" (*Elops saurus*) and the "jack" (*Caranx hippos*) found in the east side. Mr. Thomas stated that a similar ratio has existed each time the locks have been drained for overhauling, which is done at intervals of about three years. The writer knows no reason for the difference in the abundance of the fish in the opposite sides of the locks. The information is given here merely as a matter of interest.

Only the two smallest tarpons taken in the locks, respectively 3 feet 3 inches and 3 feet 7 inches long, were males, both being nearly ripe. Of the seven females one contained large roe, one small roe and the others were undeveloped.

Tarpons generally are numerous at the foot of the spillway, a high concrete structure built in the great Gatun dam. The dam itself is so large and broad that a golf course is maintained on it. The dam and spillway together hold the large body of water known as Gatun Lake, which forms a considerable portion of the canal. The water necessary for operating the locks is obtained from this lake. When there is a surplus it is used in generating electricity for operating the machinery connected with the locks, and when there is still a further surplus of water it spills over the spillway from the level of the full lake to the old bed of the Chagres River near sea level. The water from the turbines, too, enters the old bed of the Chagres River below the spillway. It is in this usually greatly disturbed water that tarpons collect. Here the water was fairly astir with tarpons and other brackish and marine fishes when the writer made observations in January and again in March, 1924. I did not find the opportunity to revisit this particular spot in 1935, but was informed that the situation remained unchanged. At the time of my visits the anglers present (Americans) stated they did not care to catch tarpons there, as the fish were so numerous and so easily caught it was not considered sport. The fish seen and taken were rather small, all under three feet. It is understood, however, that large ones do frequent this place.

The late Dr. Seth E. Meek and the writer, while collecting cold-blooded vertebrates in Panama in connection with the Smithsonian biological survey of the Canal Zone in 1911 and 1912, found small tarpons, ranging in length from 12 to about 24 inches, rather common in the brackish water in the vicinity of Mindi and New Gatun, that is, along the sea level end of the canal. Also, one large one, 5 feet or so in length, delivered itself into the collectors' skiff in that vicinity by leaping high in the air, "landing" first on Dr. Meek's back (hurting him somewhat and frightening him badly) and then falling into the boat. Its head slipped under a thwart, giving the writer a chance to administer a stunning blow with an oar. No tarpons were seen in strictly fresh water at that time, that is, before Gatun Lake had been formed. The area now included in the basin of the lake was thoroughly sampled in 1911 and 1912, and it is believed that if tar-

pons had been present they would have been found.

Discussions

It is very evident from the foregoing remarks that tarpons are fairly common in Gatun Lake and that they also occur in Miraflores Lake. It does not follow, however, that tarpons spend their entire lives in these fresh-water lakes, for if the complete life cycle were carried out there the larvae (*leptocephali*) and small tarpons should be present. It has been shown in the preceding pages that during a fairly thorough search no larvae and no small tarpons were seen in the lakes.

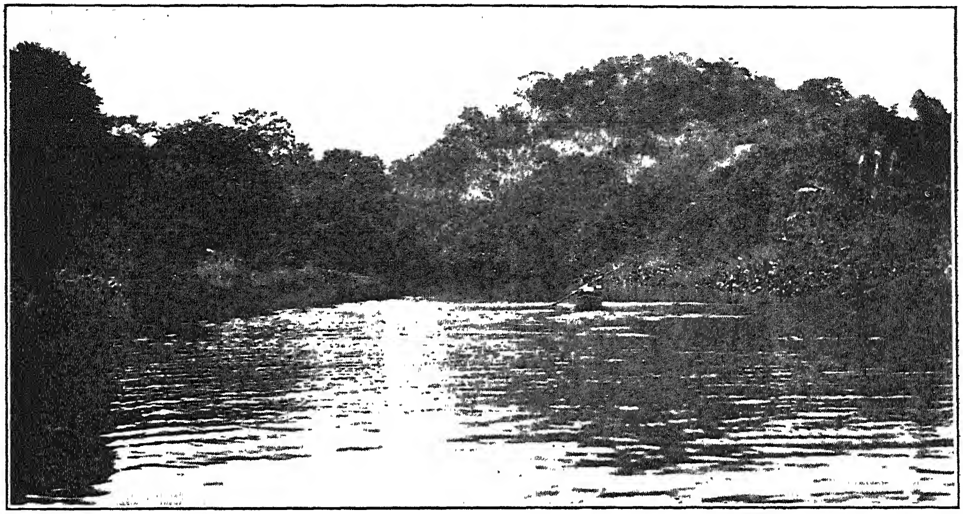
Tarpons could reach Miraflores Lake only by passing through Culebra Cut and Pedro Miguel Locks, for the Pacific Ocean is not the home of the tarpon, as already stated. Since tarpons have reached Miraflores Lake by passing through the Pedro Miguel Locks, the writer knows of no reason why they can not go on to Panama Bay and the Pacific Ocean through the Miraflores Locks. However, to date the tarpon has not been reported from the Pacific.

Since it is definitely known that tarpons have passed through the Pedro Miguel Locks, it may be assumed with certainty that they also pass through the Gatun Locks. If the fish did not reach Gatun Lake by that route it would have to be assumed that they were present when Gatun Dam was closed in 1913, and that the fish now in the lake either were there in 1913 or have reproduced in the lake.

There is no evidence that tarpons were present in the vicinity, which now is the lake basin, before the dam was closed, as already stated. Furthermore, fish present as early as 1913 would be very old now, much older than the age usually attained by fish. Then, too, the fish would be expected, unless there was reproduction, to become scarcer from year to year. According to information obtained the fish, however, are increasing rather than decreasing in abundance. It seems highly improbable that reproduction is taking place within the lake, since the evidence obtained during the recent investigation, as already shown, is entirely negative.

It has been stated in the preceding pages that several tarpons were present in the Gatun Locks when they were dewatered in February, 1935. According to Mr. H. M. Thomas, assistant superintendent of the Gatun Locks (who has supervised the periodical draining of the locks from the beginning) some tarpons were stranded each time the locks have been dewatered. It is the opinion of the writer that the tarpons that are stranded, when the locks are drained, are not necessarily actually in transit either to or from the lake. It is believed, rather, that the locks are used by the tarpons (and several other fishes) as feeding grounds, for small fish and crustaceans were quite numerous during the recent inspection, and it seems probable that a new supply of food is brought down from the lake or enters from the sea level end of the canal when the locks are operated. The locks apparently are used, therefore, as feeding grounds, somewhat like the base of the spillway where large numbers of tarpons (and other species) collect, as already stated. However, the fish appear to stray away from the feeding grounds within the locks from time to time, some no doubt returning to the sea, whereas others pass on into Gatun Lake, and a few of these eventually go on across that lake, through Culebra Cut, the Pedro Miguel Locks and on into Miraflores Lake.

If the fish can pass through the locks to Gatun Lake they surely can return by the same route. The fish, indeed, had to pass "down" and through the Pedro Miguel Locks in order to reach Miraflores Lake. Therefore, they certainly can, and no doubt do, go "down" the Gatun Locks



THE MOUTH OF THE RIO COCOLI, MIRAFLORES LAKE
WHERE TARPONS ARE OCCASIONALLY SEEN.

and out to sea at will, or as the necessities of life or reproduction require it.

The foregoing remarks seem to require an explanation, for the benefit of the reader who may not be familiar with the construction and operation of the locks of the Panama Canal, of how the fish manage to pass through the apparent obstruction.

A brief description of the passage of a vessel through Gatun Locks will illustrate also how a fish—a tarpon, for example—may find its way through the locks of the Panama Canal. In the first place Gatun Lake when full is about 85 feet above mean sea level. Therefore, a vessel passing from the Atlantic Ocean to Gatun Lake must be lifted from sea level to the level of the lake. This is done with a series of three equal lifts in close succession. The boat enters the lowest chamber of the locks at sea level. Heavy iron gates are closed behind it. Water is let in from Gatun Lake until the water level of this chamber reaches that of the second or middle one. Then the gates in advance of the vessel swing open and the boat enters the middle chamber. Now the seaward gates of this chamber are closed behind the vessel, and as before water is let in from Gatun Lake until the water level of the middle chamber equals that of the upper one. When that level is reached the gates at the bow of the vessel are opened and the boat passes on to the third or upper chamber of the locks. After the gates between the second and third chambers have been closed the water in the upper one is raised to the level of Gatun Lake. The vessel is now ready to sail out into Gatun Lake. To lower a vessel from Gatun Lake to the sea the process, of course, simply is reversed.

The locks on the Pacific side are operated in the same way. There is only the difference that the three flights are not all together. One flight is located at Pedro Miguel and two are at Miraflores on the other side of Miraflores Lake about four miles away.

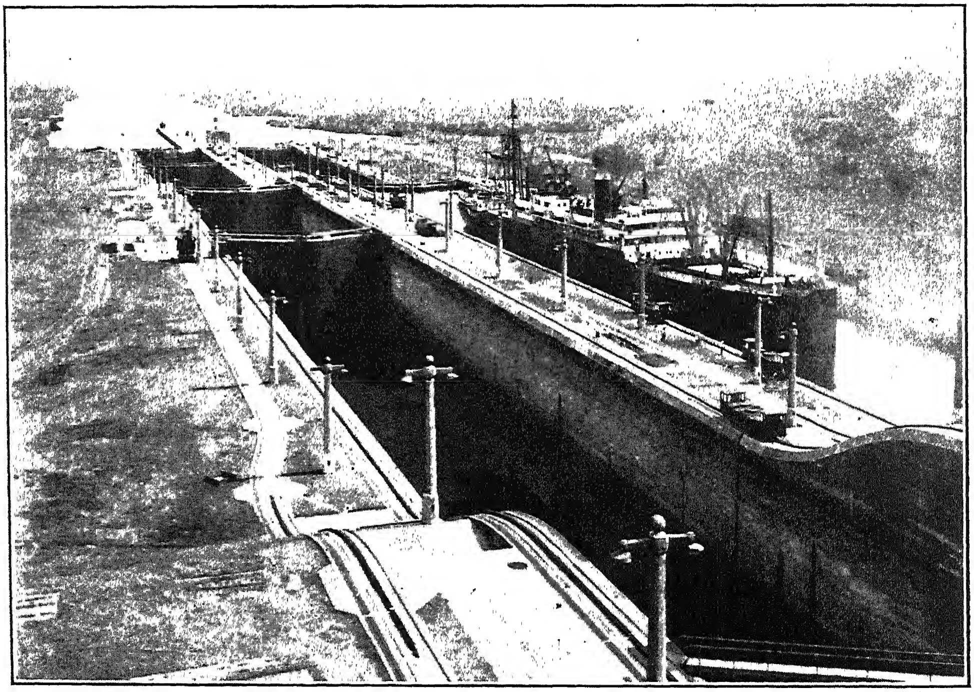
A fish certainly could follow a vessel through the locks in either direction, providing of course that it could endure the rather sudden change from salt to fresh water or *vice versa*. However, the fish

does not have to pass through the entire series with any one vessel, as each chamber contains ample water at all times for the welfare of the fish. Therefore, it may stop in any one chamber for an indefinite period of time, providing sufficient food is present. Should food become scarce, or the *wanderlust* get strong, or the urge to spawn come, the fish may follow a vessel to a higher or lower level. Or it even may go from one chamber to the next (one at a time) in the direction opposite to the course of the vessel, as there is nothing to prevent it from swimming from one chamber into the next one while the gates are open.

It is evident from the foregoing discussion that the chief barrier to fish formed by the locks is the change from salt to fresh water and *vice versa.* A fish that can endure such changes in density should have no difficulty in passing through the locks. The tarpon evidently can accommodate itself to such differences in salinity, and the evidence at hand, as already indicated, shows quite conclusively that this fish does use the Gatun Locks (and the Miraflores Locks to some extent) as a passageway and probably as a feeding ground.[3]

It has been stated that three ripe or nearly ripe tarpons (two males and one

[3] Since this manuscript was prepared the writer has examined the air bladders of several tarpons and found that they contain a comparatively large amount of lung tissue showing that the fish are not entirely dependent upon their gills for oxygen, which may be the reason why they can change from salt to fresh water and *vice versa.* A full account, with a figure of the structure of the air bladder of the tarpon, is included in Mr. Louis Babcock's book "The Tarpon" (Fourth Edition), 1936, pages 48 to 50.



Courtesy Panama Canal

GATUN LOCKS, SHOWING SEA-LEVEL END OF CANAL

IN BACKGROUND. ONE SIDE OF LOCKS IS EMPTY; A SHIP IS IN TRANSIT "UP" THE LOCKS (MIDDLE CHAMBER) IN THE OTHER SIDE.

female) were present among nine specimens examined in the dewatered locks at Gatun. No evidence whatsoever indicating that the tarpon spawns in the fresh waters of the Panama Canal was secured. It seems probable, therefore, that the ripe fish seen in the locks were enroute to their spawning grounds somewhere in the sea.

It was stated in the introductory remarks to this paper that the spawning grounds of the tarpon have not been found. Neither has the recent investigation helped greatly to discover the secret. It can only be stated here, as already shown, that the results of the investigation indicate that the tarpon does not spawn in the fresh waters of the Panama Canal.

Several investigators have taken young tarpons, all past the larval stage, in shallow salt and brackish water lagoons, as pointed out in the introductory remarks. It does not follow, however, that such places are spawning grounds. In fact, it is highly improbable that large fish, like the tarpon, would go to such places to spawn. Furthermore, the leptocephali undoubtedly would have been taken before now if they occurred in such places or in inshore waters. The writer ventures the opinion that tarpons very probably spawn quite a distance off shore and in deep water.

The young, as already stated, pass through a leptocephalus stage like the eels. It seems entirely possible that tarpon larvae, like fresh-water eel larvae, travel long distances. The larvae of the European eel are known to cross the Atlantic Ocean from deep water, lying between Bermuda and the West Indies, and those of the American eel migrate from the same general vicinity to the American shores. The young eels do not attain the adult form until they reach the mouths of the rivers they ascend, at the age of about one year for the American and about three years for the European eel. It does not seem unlikely therefore that tarpons, too, spawn considerable distances off shore and that the young make long migrations. The single specimen in transition from the leptocephalus to the adult stage, described by the present writer (see reference in the introduction), taken in an estuary at Beaufort, N. C., may have been enroute to a quiet, shallow lagoon or swamp, for such places appear to be frequented by small tarpons. In the light of the evidence offered the writer would search for the leptocephali of the tarpon in offshore waters.

It has been stated on a preceding page that it has been supposed tarpons spawn in the spring and summer on the west coast of Florida. Investigators arrived at this conclusion because fish with large roe have been taken there during that time. By the same criterion, it may be deducted that spawning probably takes place off the coast of Panama during the winter and spring, the entire period during which fish with large roe occur there having not been determined.

Summary

Some important published information concerning the life history of the tarpon is reviewed. It is evident from this information that much of the life history of the tarpon remains unknown.

The occurrence of the tarpon in the waters of the Panama Canal is discussed, the discussion being based largely on investigations and observations made in 1911, 1912, 1924, and especially in 1935. It is shown that tarpons were present and apparently rather common, in the brackish to fresh water swamps and canals in the vicinity of Mindi and New Gatun in 1911 and 1912, before the canal was completed. It is stated, also, that no tarpons were found at that time in swamps and streams now included in the basin of Gatun Lake. In 1924 tarpons were numerous at the base of the spill-

way of Gatun Lake, a situation which apparently remained unchanged in 1935. Adult tarpons were common in some parts of Gatun Lake in 1935, and they also had reached Miraflores Lake, from whence they apparently may descend to Panama Bay, though no evidence has been secured that this has taken place. Young tarpons were mistakenly reported by native fishermen from Gatun Lake. No evidence was secured that they occur there.

Several large tarpons were stranded when the Gatun Locks were drained for overhauling in 1935. According to information offered by canal employes tarpons have been stranded there at each previous dewatering.

It seems probable that the Gatun Locks are used more or less regularly as a passageway, and probably to some extent as a feeding ground, by tarpons. Fish should not find it difficult to pass through the Panama Canal Locks in either direction, providing they can endure the change from salt to fresh water or *vice versa.* The tarpon evidently can endure the change. An explanation of how the fish may go through the locks is offered.

Three of the nine large tarpons examined when stranded during the drainage of Gatun Locks in February, 1935, contained large roe, indicating that at least some of the fish in the latitude of Panama spawn during that month.

The spawning grounds of the tarpon remain unknown. The author expresses the opinion, supported by some evidence, that they probably lie in deep water some distance off shore.

Tarpons pass through a leptocephalus stage, but the leptocephali have not been found. A specimen in transition from the leptocephalus to the adult stage, however, has been described.

Acknowledgments

The writer wishes to express his sincere gratitude to Dr. Herbert C. Clark, director of the Gorgas Memorial Laboratory; to Major W. E. R. Covell, in charge of maintenance of the Panama Canal; to Mr. H. M. Thomas, assistant superintendent of the Gatun Locks; to W. H. W. Komp, of the U. S. Public Health Service; and to Mr. R. A. Cauthers, in charge of maintenance at Pedro Miguel, for assistance given in various ways. Without the cooperation of these gentlemen the investigation could not have been made. Special thanks are due Dr. E. W. Gudger for reading the manuscript and making valuable suggestions.

THE MEDICINE OF HISTORY

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UNDERSTANDING of any subject requires its observation from the largest possible number of view-points. In these days, when the manufacture of history is speeded up so highly, there is need of every possible view-point on history in order to understand the present, to use the past and to plan for the future. It is probable that medicine, as a discipline and a method, may provide a view-point of history different from and complementary to other view-points. The medical study of history certainly is not the only, and perhaps even is not the most important aspect of history. But without its medical components, history is much more difficult to understand and to explain. International relations develop out of domestic conditions and in both the health of individuals, leaders as well as populace, has a modifying and sometimes a controlling effect on the production and course of events. Again, the health of social aggregations of people en masse frequently influences their domestic as well as their external conduct. Understanding of these individual and national or social health conditions often explains historical events. The great difficulty here is that man is not inclined to use and apply scientific knowledge in connection with social problems.

ECONOMICS

More than on anything else, international relations and national histories are dependent on economics. For schematic purposes, economics can be reduced to sources of production, utilization of products and that great connecting link, communications. Each of these three has definite medical features, but none of them has yet received adequate consideration from the medical point of view.

COMMUNICATIONS

Communications includes the transfer of persons, commodities and ideas. Its story is the story of human culture and advancement. Originally limited to his own foot power, man has harnessed animals, steam, electricity, oceans and winds, made internal combustion engines and utilized the principles of the inclined plane, the lever and gravity, all to facilitate his means of transport. As new methods have been discovered, old ones have not been abandoned but merely reoriented for use. Speech has been augmented by writing, printing, telephone, telegraph, radio and teletype. Locomotion has advanced from land to sea and then to air. Each advance in transport methods has invariably brought new and unique problems of control. Traffic management always has unsolved problems because improvements can not be foreseen and old solutions are inapplicable.

Disease control is complicated by all forms of air travel, which in turn have made necessary a completely new division of medicine dealing with the selection of pilots and the safety of air passengers. The hazards of air transport have an important medical aspect both in prevention and in treatment of abnormal states resulting. The opening of new automobile highways, as in the case of the new route to Mexico City from the Rio Grande, brings problems of disease transfer in each direction by man, insects and other animal carriers; the problem of adequate eating and drink-

ing facilities both for normal nutrition and for disease prevention; the problem of hospital, first-aid and other medical service in route; and the problem of adjustment to changed climatic factors.

The serious increase of traffic accidents and deaths in the United States carries medicine at a bound into the field of engineering, road construction, police control, public education and fitness of drivers. Improved communications developed the present world-wide system of collection of vital statistics and contagious disease incidence. Famine prevention, epidemic control, disaster relief and quarantine are other outgrowths. Quarantine was instituted by the Venetians and Lombardians in the fourteenth century to inhibit commerce for the sake of excluding epidemic disease (plague) coming in from the Levant. To-day quarantine facilitates commerce by scientific control of the causes of epidemic disease. Such an extension of medical service was not dreamed of a few years ago. It illustrates the intimate relation between medicine and communications.

Population Pressure

The basic principles of economics—production, utilization and communications—have had among others two practical developments which also have important medical phases. They have eventuated socially first in population pressure. This is a variable principle. It is qualitative and not quantitative. Some regions are over-populated with two persons per square mile. Population pressure depends on the ability of a geographic region to support its inhabitants in reasonable comfort and happiness. It is a direct result of economic relations and it is itself a medical problem because individual and collective health are so closely connected with population density. Health is affected by the economic standard of living, by the culture types modified or produced by quantity of population, by the degree of sanitary control and by facilities for prevention of disease transfer. Death and birth rates become of primary importance and assume an intricate reciprocal relationship with the other factors just noted. Infant survival and birth control are closely connected with religious, economic and cultural ideas, which tend to become compulsive. Population pressure tends to natural readjustment of equilibrium, and when this natural course affects nationalism or national economics, artificial controls tend to appear. These in turn lead to social unrest, disputes and wars.

Military Establishment

The second great development from basic economic principles is the growth of the police power and the entire military establishment. As man assumes social relations, social restraints become necessary, unless he is to live in that state of exalted individualism called anarchy. Social restraints lead to the institution of police power, which is as important from the health standpoint as with reference to crime prevention. National military establishments are part of the institution. Their effectiveness rests primarily on health considerations, just as their utilization is based on original economic causes. Domestic health of a nation is improved and maintained by various applications of police power. Wars and international economic competitions at once reflect health states in the countries concerned.

A verse by Ogden Nash expresses the mixed forces of social and economic restraints, militarism and population pressure.

> The turtle lives 'twixt plated decks,
> Which practically conceal its sex.
> I think it clever of the turtle,
> In such a fix to be so fertile.

Definitions

Before proceeding to illustrate our subject from the evidence of history itself,

it is well to establish a few definitions. These will make more definite what is meant by the influence of medicine on history, or what we call in brief the medicine of history.

In the first place, the term "nation" has often very inexact connotations. By it we mean here an aggregation of people having in common one or more of three things—a common origin, a common history or a common language.

In the second place, we define medicine, in the words of Webster, as the prevention, cure and alleviation of disease. Nothing is said as to systems or cults or sectarian ideas, all of which have no meaning for the real physician. The collection and utilization of all agents and methods from any and all sources, which may be of use in the specific case at issue, is the province and custom of medicine. Medicine therefore is concerned with study and improvement of the state of health of the individual and of social aggregates.

In the third place, we must define health, a most difficult thing to do because health may be good or bad or mixed, and because health is a composite of so many variable factors. Perhaps the best definition is to call health the average relationship between the individual and his environment. To study or evaluate health then requires exhaustive study of the total environment, a field properly called environmental medicine.[1] Reflection makes it plain that to draw a sharp line of demarcation between individual and environment is most difficult. To change or remove the individual at once radically changes the environment. To change the environment at once changes the individual. The two interpenetrate to a confusing degree. The philosopher would say that they are the same. The biologist would set up rather arbitrary and elastic boundaries as working hypotheses in his study. From the standpoint of history, attention must be given to the enormous influence on health of the environment of which the individual is a part. The interplay between the hereditary endowment (individual or racial) and the compelling force of environment must be understood in order to understand why individuals and nations act as they have acted.

[1] See A. C. Reed, *Science*, November 15, 1935. Also see J. W. Bewes, "Human Ecology," Oxford University Press, 1935.

Individual Illustrations

All historical characters lend themselves to illustration of the proposition that individual health has a bearing on public acts and policies. A few may be selected at random, from Julius Caesar, whose powerful sex urge was turned into channels of military organization and achievement, down to the leading dictators of our time. Napoleon showed the interesting combination of great egotism, vigor and driving energy in a man physically small. His compensations and adjustments furnish an illuminating commentary on his career and on the development of his great genius and world-embracing vision. It is to be noted that his post-mortem examination showed a complete atrophy of the testicles, and one can not help wondering as to the correlation between this progressive atrophy and the declension of his political and military genius. Failing physical vigor easily leads to a compensating program which may be grandiose and even fanciful in a person of driving imagination and egotism. We would like to know about the condition of Napoleon's cerebral arteries. His death from gastric cancer was a terminal accident which did not concern his earlier public life.

The sixteenth century saw the rise of England's great King Henry VIII, the man who rescued England from her insularity and made her a nation with world influence and destiny. He it was, the first sailor king, who laid the founda-

tions of British sea trade and the British navy. A man of aggressive strength, both physical and mental, he showed two outstanding medical peculiarities. He was unable to produce a male heir who could succeed him, and in his early middle life he began a progressive physical and mental degeneration which terminated in his death. Both of these things had serious and determining results on the English succession and on English history. Both were due to the spirochetes of syphilis. The spirochete which causes syphilis is no respecter of persons and is strangely as uninfluenced by ignorance of its presence as it is by disbelief in its potency. It did for Henry VIII very efficiently and conclusively. What he would have done and what England might have become, lacking the activities of the spirochetes in Henry's brain, is a matter for speculation only. Whether for worse or for better, in any case, both would have been considerably different. Even his matrimonial succession would have been greatly altered.

It is doubtful if history records an example of sheer cruelty, sadism and mass torture that exceeds the record of Ivan the Terrible. His wholesale murder of populations and his innumerable tortures and murders of individuals and groups flowed in a steady stream from another brain invaded by the spirochetes of syphilis. The result was a set-back to Russian social progress which even the great Catherine could not undo.

Queen Elizabeth may have owed her physical and psychologic make-up to the abnormalities of her father, Henry VIII. There is no doubt that her masculinity strongly influenced her public policies and also prevented her from ever marrying. Following the new policy of her father, she stimulated the formation of the British empire in India through the English East India Companies and at home consolidated the central power of England. While her unmarried state held a constant lure before the diplomats of Europe, it also settled the English succession. A normal femininity might not have led to better or worse results, but they certainly would have been different.

In 1412 there appeared a figure who changed the story of France and became one of the world's most tragic and romantic heroines, Joan of Arc, the illiterate peasant girl of Domremy, who died at the age of 19, without ever experiencing normal adolescence. In place of sexual maturity she heard voices and developed a mystical sense of mission and leadership which were abundant compensations and which fully explained the superstitious awe in which she was first held and the bitter animosity which she later aroused. Aberrations of physiology were associated with compensatory aberrations of psychology. Sex repression and infantilism pursued their characteristic course. And the result was an impact on history and legend, and the production of a half-mystical figure differing surprisingly in meaning, whether observed from the emotional or the rational point of view.

One other feminine figure of history must be mentioned, the Empress Theodora. In the sixth century, the austere and ascetic Justinian, emperor of the Eastern Roman Empire, at the age of 40 married the 20-year-old Theodora, courtesan and prostitute of Byzantium, whose reputation almost rivaled in extent that of the emperor himself. With her elevation, Theodora seems to have turned her charm of personality and great intellectual force into new channels. Her origin, background and earlier life combined with her mental vigor to make inevitable the remarkable influence she had on Justinian when he codified Roman law in his Institutes and Code. Here for the first time woman was accorded definite civic rights. Theodora was perhaps the first great feminist and

her influence has been multiplied down to the present. It is understandable only when her story is understood with its psychologic and physiologic foundations.

It is worthy of passing comment that Nietzsche and Lenin both suffered from syphilis of the brain, and general paresis is notorious for its tendency to grandiose delusions and unsettled judgment. Coming down to more recent times, we note the tragic pair of the great war, Kaiser Wilhelm II and Woodrow Wilson. The withered arm and efforts at compensation in the former accompanied mental brilliance, overweening ego, unbalanced judgment and eventually perhaps a paranoid status. The calming effect of asylum life, whether at Doorn or at some well-recognized institution in the United States, is well known. One can only speculate as to when Woodrow Wilson began to be influenced by the progressive degeneration of his cerebral arteries, which finally wrecked him. Certainly an effective cerebral circulation might have modified his courses and given him more vigor to carry them through.

We have then finally to consider the application of a medical summary to the two leading present-day dictators. The excellent studies of John Gunther on Hitler can be summarized in a few words. Gunther finds Hitler to be a man lacking in education and culture in any sense of the terms, a man who never reads, who is essentially weak and whose asceticism is born out of fear of temptation. He apparently is not a sex pervert, and on the contrary seems to have no sex interest, due to infantile fixations. Gunther characterizes him as a frustrated hysteric whose only release is in speaking. Such a summary surely lends understanding to a character otherwise most difficult of interpretation.

The other front-page dictator, Mussolini, is characterized by Gunther as a man highly educated and sophisticated, in robust health, whose hero is Julius Caesar, and who, being of the same height (5 feet 6 inches) as Napoleon, also likes to wear a corporal's uniform. He is very superstitious and violently in love with violent movement and speed. Out of his early and frequent prison experience, he has developed a claustrophobia, a fear of closed places. He is a man of tremendous egotism and megalomania, out of which, one might interpolate, are easily grown the seeds of paranoia.

Such illustrations, selected rather at random from an abundance of historical figures, show that the conduct of men in public as well as in private life can be influenced, modified and even controlled by purely medical factors of individual health. Hardened arteries, grandiose ideas, psychologic repressions and physical disease due to infections, reflect their results in events. History has a large medical component, which contributes in no small degree to understanding of history itself.

Mass Illustrations

We turn now to the effects of various states of health, that is, various medical factors, which are related to the history of man en masse, of social aggregates, nations and races. Once more we must start with the principles of human ecology and communications, which have been summarized above.

Human Geography

Human geography comprehends the bearing on human health and activity of geographic factors of the environment. Bowman, in his wonderfully stimulating book, "Geography and the Social Sciences" (1934), says:

> Earth facts do not determine the form and nature of human society in development. They condition it. . . . The relations are reciprocal. There is nothing in earth facts as such which inexorably dictates public policies, either national as in the case of the conservation of

limited resources, or international with reference to the distribution of such resources throughout political divisions and sub-divisions. Such facts, we repeat, condition policies but do not determine them. . . . Earth facts change in significance with man's changing activities, his useful or wasteful exploitation. . . . Thus while particular scholars may confine their attention almost entirely to so-called objective earth facts, those who *select* earth facts and organize them in relation to mankind are operating with respect to social knowledge and thought as well as with respect to earth facts.

The same idea is developed by J. W. Bewes in "Human Ecology" (1935). He says: "It must always be remembered that the functional relationship between environment and organism is a reciprocal one. The organism also continuously influences the environment." In his introduction to this volume, General J. C. Smuts, after epitomizing his own holistic doctrine, says: "The organism is not itself alone and in isolation. As a unit it is a mere static abstraction. The real dynamic unit is the organism functioning in its environment. . . . Life is living and living is an active reciprocal relation between organism and environment." Such is the essence of the thing called human geography. Because our means of observation are limited, it is much easier to trace the effects of environment on man en masse, in social aggregates, than on man as an individual. In the first place, then, our consideration extends to the broad subject of the relation of geographic environment to human history.

Illustrations of this topic are numerous and include most of the emigrations, racial and tribal transfers, that man has undertaken. Specifically a few examples may be noted.

In the twelfth century various environmental factors operated to stimulate a population outflow from the plateaux of central Asia. Population pressure became stronger as pasturage and water supply decreased. The Golden Horde poured out in three great waves. The first under Genghis Khan overflowed north China and for over two centuries fostered the Mongol-Chinese fusion which is still so much in evidence. The second wave flowed in successive inundations over the plains of north India, eventuating in the magnificence and high social organization of the Mogul (Mongol) dynasty whose imprint is imperishably fixed on Indian architecture, religion, politics and social structure. The third wave inundated Russia and for more than 200 years mongolized the government and people, leaving residues of Tartar blood which may help explain the history and the personality of Russia down to the present.

Again we see the story of the gradual drying up of Arabia and Mesopotamia. A land supporting probably nine million inhabitants was reduced to a capacity of about three millions. In the seventh century came the Prophet of Allah, with his invigorating and unifying evangelistic fervor. The Moslem started out westward. Egypt and all north Africa to the Atlantic fell before him. Then, strangely, this man of the desert, this horseman and nomad, this fanatical fighter, turned northward across the water into Spain, and never crossed the Sahara into the lush equatorial richness of Africa. The tsetse fly guarded the southern reaches of the Sahara and killed horses and live stock on which the Arab depended for life and transport. The resulting cultural increment in Spain was only interrupted when Ferdinand finally expelled the Moors in 1492. So much hinged on geography and geographic insects.

We find another illustration in Egypt, whose ancient glory fell before the onslaught of two lowly worms, Bilharzia and hookworm. The conquest of these two by scientific medicine in our own day may help materially in rebuilding the old foundations. So changing environment brought the anopheles mosquito to Greece

and to Rome, and the mosquito conquered great nations by the weapon of malaria. The story of the Conquistadores is shot through with medical hazards which changed, retarded and even stimulated the Spanish lust for gold and converts. The health of the world, through its communications, has been deeply influenced by man's controlled change of environment in building the great canals, Suez and Panama. These are a few demonstrations of human ecology, of the influence of environment on health condition en masse, of medical geography.

Epidemics

Social aggregates of mankind have been profoundly influenced since remotest times by epidemics. The record of plague is particularly interesting. Sweeping through Athens in the fifth century, B.C., it weakened the Attic manpower, paved the way for the Athenian defeat at Syracuse, probably struck down Pericles and was followed by the fall of the Golden Age of Hellas. In Justinian's time plague is said to have removed one third of the population of Byzantium. In the fourteenth century its fury was felt and the story was told for London by De Foe and Pepys. The epidemic of pneumonic plague in Manchuria in 1910, through the skilled leadership of Dr. Richard P. Strong and his American colleagues, led to practical methods of protection for the first time. To-day we see plague well established in the wild rodents over large sections of California and extending north and eastward to an unknown degree, with constant danger of human spread.

The story of typhus fever, as a war-attendant, as a scourge of populations and in its individual results has been well set out by Dr. Hans Zinsser. The records of cholera, yellow fever, smallpox and even measles are well known. Non-immune populations die like flies before these epidemics, as when measles depopulated many islands of the South Seas and in 1806 killed one third of the California Indians. Not fear, not an idea, not an immaterial emanation has done these things, but the unhuman and merciless virulence of germ and virus. Protection has never lain with magic, incense or refusal to recognize reality, but alone and always with scientific knowledge scientifically applied. The social scars of epidemics are not always lasting. In this they differ from endemic diseases. Influenza, in 1918–19, killed ruthlessly and then was gone. It did not drag out in chronic invalidism, social inefficiency and reduced physical and mental vigor. Nonetheless, epidemics have profoundly modified history and the course of events and have lost to mankind a huge amount of sadly needed intellectual, physical, moral and creative ability.

Endemics

Endemic diseases develop their natural history continuously in one place. Instead of periodic waves of pathologic activity and epidemic cycles, they operate steadily and, therefore, as has been indicated, are more prone to cause steady or even progressive social deterioration and ill health. Their morbidity rate is more important than their death rate. They weaken populations and individuals, reduce human initiative and predispose to other diseases. They depend on maintenance of natural balance between disease and host which, however, too easily operates to the disadvantage of the host. It is possible that the best biologic solution of the problem of epidemics would be to reduce them to a low rate of mild endemicity. Endemic disease in many instances has been a serious menace to human institutions and culture.

Such instances are seen in the world-problem of malaria. One chief reliance in treatment has become the effort to develop and utilize acquired immunity, but its attainment is attended too often by

uncontrolled and disastrous consequences. It is doubtful if the world-mass of malaria has yet been reduced, certainly not significantly, by the past 35 years of more exact knowledge of this disease. Malaria eradication is still too expensive in cost of personnel and engineering methods. And as soon as the flow of money is curtailed, malaria returns to its former preserves. We have no complete, cheap, safe and efficient method of cure or of prevention. Probably no disease to-day has a greater incidence the world around. Along with these considerations, the historian observes the racial weakening and backwardness, the social inefficiency and deterioration, which malaria produces. Its effects are evident in countless examples, from Greece and Rome, to southern Asia and the New World. Everywhere its ravages can be measured in social terms. Multiply this by the centuries of its parasitic existence and we have a problem worthy of the enormous expenditures of effort and money directed against it. We have, too, some appreciation of the effects of this disease on history, too often growing into a vicious circle where a weakened population sees its defences against malaria thereby further weakened. It is of course not a hopeless problem. For only a third of a century has the nature of malaria been understood. Human brains will triumph, and we can then forecast a renascence of peoples and regions now lying under its shadow.

Leprosy is another endemic disease with vast influence on the history of mankind. Here again natural and largely unknown causes, possibly aided by segregation, have considerably changed the habitat of the disease. There were doubtless good reasons why the discovery of America by Leif Ericson in the ninth century and the explorations of his successors never developed into a settled colonization. Among these reasons, probably, we can place the prevalence of leprosy in Scandinavia, which was a problem of sufficient weight to tax the public resources. Europe of the fourteenth century had some 22,000 leprosaria, over 2,000 in France alone. To-day this curious disease is dying out among the blacks of Brazil and increasing among the blacks of central Africa. The form of its infecting agent and the means of its spread are not definitely known. Yet as a public health problem the road to its solution seems open.

Hookworm disease has many parallels with malaria in its social significance. African sleeping sickness has kept the rich heart of a rich continent nearly barren of human culture. Syphilis takes its social toll and the slow process of racial immunity does not far outstrip effective methods of treatment and prevention. And so, through a long list, endemic disease makes its mark on history and all too often controls or modifies man's destiny.

Other Medical Factors

The influence of communications on the health state of nations has already been commented on. A corollary is the relationship of communications to famines and to relief after natural disaster, such as fire, flood and earthquake.

Health states are profoundly affected and not infrequently controlled by ideas of religion, sex and social organization. These are exemplified in every religion and in our own social order and can receive here mention rather than discussion.

Conclusion

The health of nations and of individuals exercises a potent influence on the manufacture of events and policies. The medicine of history may not always furnish historical causes, but it often and usually conditions human proceedings. For the fullest understanding of history the medical point of view has a clear contribution and can not be neglected.

RACIAL FOOD HABITS IN RELATION TO HEALTH

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In the not very remote past man tried to appease the forces of his environment which were hostile to him by offering prayers and libations. The development of modern science has taught him that the environment may be controlled instead of appeased if he will learn the nature of the forces operating in it. The great mission of science is to put man en rapport with the forces of nature. The most modern science, nutrition, deals with the control of health in so far as it is affected by food—which is much farther than most people yet realize.

In the early pioneer days, when settlers were moving into the Middle West, a group of travelers came upon a lovely spot; water sparkling from a clear spring; all about was fresh verdure for their cattle. They encamped with joy, but this was soon turned to weeping, for the cattle sickened and the children who drank their milk died. From that region all fled in frantic fear as from a plague. What was the strange sickness which cursed so fair a spot? It took forty years to unravel the mystery of the so-called "milk sickness." Sometimes outbreaks swept away so many of the population that entire communities were abandoned. In 1927 it was discovered[1] that the disease was due to a plant which flourished throughout the eastern part of the United States and as far west as Nebraska and Oklahoma, called the richweed or the white snakeroot. With present-day knowledge, milk sickness is conquered by eradicating the obnoxious weed, not by running away from the spot where it grows.

Twenty years ago, when pellagra was a scourge in many a poor mill town of the South, the development of the disease in a family was a signal for the neighbors on either side to depart. They thought they were moving away from infection, but what really saved them was moving into a region of different food. It was many years after the first suspicion had dawned in the minds of scientists that pellagra might be associated with dietary deficiency before Goldberger and his associates in the U. S. Public Health Service were able to show that symptoms of the disease could be produced experimentally and cured again by dietary measures. Goldberger's experience taught him that "the suspicion of pellagra may with confidence be dismissed in one who is a habitual milk drinker and meat eater," and his successors, Wheeler and Sebrell, express the same idea thus: "In looking for cases of pellagra, the home surrounded by evidence of a good garden or a cow or two, a few pigs and some poultry, may as well be passed up (in the survey), for the chances are less than one in a thousand that pellagra will be found. On the other hand the home surrounded by last year's cotton patch will always bear watching."[2]

A field study recently made in South Carolina by Stiebeling and Munsell[3] affords further evidence that the distri-

[1] J. F. Couch, *Jour. Agric. Res.*, 35: 547–576, 1927.

[2] G. A. Wheeler and W. H. Sebrell, *Jour. Am. Med. Assoc.*, 99: 95–98, 1932.

[3] H. K. Stiebeling and H. E. Munsell, *U. S. Dept. Agric., Tech. Bull.*, No. 333, 1932.

bution of foods such as milk, wheat germ, yeast or canned tomatoes in suitable amounts to families in which pellagra is prevalent will greatly reduce the incidence and severity of the disease without any other change in the diet or the general living conditions. We have every reason to believe that before long researches in this field will give full control over this once mysterious scourge and explain why maize-eaters are peculiarly subject to it.

The effects of any considerable shortage of fuel for the human machine are so immediate—as evidenced by emaciation and unfitness for work—that there can be little misunderstanding concerning the need of an adequate energy supply. But partial shortages of a single essential chemical substance required in only minute daily amounts may only very, very slowly undermine health, and the connection between cause and effect is then more difficult to establish. In the famous "Wisconsin Experiment," in which all the dietary essentials known in 1906 were given to cattle in three different types of diet—(1) derived solely from the wheat plant; (2) derived solely from the oat plant, and (3) derived solely from the corn plant—it took three years to reveal that nutritional disaster would result from exclusive use of either the wheat or the oats ration, whereas good nutrition could be maintained into the second generation on the corn plant.[4] Research in many laboratories went on for about 17 years before we learned precisely what was required to make good the deficiencies of the wheat and oat plant rations. To-day we know that only three very simple and inexpensive things need be added—bone meal for calcium; common table salt for chlorine, and cod liver oil for vitamin A. These three can make all the difference between a miserable cow with a still-born calf and a fine vigorous cow with healthy offspring. No more beautiful demonstration of the triumph of the science of nutrition exists than in the contrast between the wheat-fed animals of 1907 and those on the suitably supplemented ration of 1924.

Now that we have eyes to see we find countless illustrations of the effects of inadequate diets. Many instances occur among animals living on the natural food resources of their habitat. A country gentleman in Alabama, residing in a rich alluvial belt adjacent to an area of sand dunes, was accustomed to hunt over these regions with his young son, and the son has told how his father often pointed out to him the greater size of the quail and other game in the alluvial territory as compared to those on the scrubby dunes. They had better food on the richer soil. Similarly, Larson, Duke of Mongolia,[5] has remarked that the wild horses brought in from the Gobi desert and properly fed would, even if six or seven years old, grow a couple of inches in height in a year or two and also show improvement in their teeth. McCollum has aptly said that the place to look for an old tiger is not in the wilderness but in the modern zoological garden, where he gets a scientific diet.

The controlled studies of white rats in nutrition laboratories have given a still clearer vision of the possibilities of improving health through diet. We may feed one pair of these animals a diet which will produce a fine litter of young through 30 generations, while a brother and sister pair, having the same heredity, and a diet differing only slightly from that of the other two, will grow to maturity; will be, so far as outward appearance goes, like the others but will lack the power of producing offspring. By simple changes in diet we can control the

[4] E. B. Hart, E. V. McCollum, H. Steenbock, and G. C. Humphrey, *Wis. Agric. Exp. Sta. Research Bull.* No. 17, 1911.

[5] F. A. Larson, "Larson, Duke of Mongolia." Little Brown and Company, 1930.

destiny of an animal very easily. We have it in our power to determine (1) whether it will grow or remain stationary in weight over long periods; (2) whether it will have a good appetite or so little that it dies of starvation with plenty of food in sight; (3) whether it will show the signs of old age early or maintain its vigor through a long active adult life. By means of this standard laboratory "tool," which grows 30 times as fast as a man and resembles him closely in nutritional needs, we may learn within a few years the cumulative effects of diet through many generations. Thus we have come to realize that we must not regard any race or nation's physical status as fixed, until we have found out whether better nutrition will alter it.

In case of human beings we also find in many regions very interesting examples of differences in physical vigor correlated with differences in dietary habits. One of the most striking of these has been furnished by the Rowatt Institute of Aberdeen, Scotland.[6] A study was conducted on two South African tribes, the Masai and the Kikuyu, with a view to possible improvement of the physical efficiency of the tribesmen as workers. Funds were provided under an agreement between the Colonial Office and the Government of Kenya, with the assistance of subsidies amounting to £6,000 from the Empire Marketing Board. These tribes live side by side in regions that do not differ as to climate and agricultural possibilities. The Masai are strikingly more vigorous than the Kikuyu. The fully grown Masai male is some 5 inches taller and 23 pounds heavier than the Kikuyu of corresponding age and sex. Also the muscular strength of the Masai, measured by dynamometer, is 50 per cent. greater. Similarly, the Masai women average 3 inches more in height and 27 pounds more in weight than the women of the other tribe. But the most striking differences occur among the children. Of the boys and girls up to 8 years of age, three fourths in the Masai tribe were graded as "good and very good" in physical development and none as "bad," while in the Kikuyu group, one half the boys and one third of the girls were graded as "poor to very bad" and less than one third "good to very good." The differences are more clearly indicated in the following table:

PERCENTAGE INCIDENCE OF DIFFERENT DEFECTS IN KIKUYU AND MASAI CHILDREN

	Kikuyu		Masai	
	Male	Female	Male	Female
Bony deformities	62.6	43.7	11.7	14.6
Dental caries ..	13.7	13.1	1.6	3.6
Dental defects in general	40.0	28.8	8.3	7.3

What are the dietary conditions which make these differences? The Masai are a pastoral tribe and live mainly on milk, meat and freshly drawn blood. The Kikuyu raise large herds of goats but treasure them as a source of wealth and honor, *i.e.*, as money, not as food, subsisting mostly on cereals, roots and legumes. That the tribe does not die out is due to the fact that certain green leaves are definitely reserved for the women and that the children of both sexes up to 5 years of age as well as the women are given the ashes obtained by burning certain swamp plants and also edible earths from available salt licks.

All races of men have the same nutritional needs. They may be met in a great variety of ways, but all the essentials of an adequate diet must be furnished in suitable amounts or else there will ensue signs of nutritional insufficiency, as in the case of the Kikuyu, among whom such nutritional diseases as bony deformities, dental caries, spongy gums, anemia, tropical ulcer and tuberculosis are rampant.

[6] J. B. Orr and J. L. Gilks, British Med. Res. Council, Special Report Series, No. 155, 1931.

What we have to do in order to understand such situations is to learn what kind of contributions different foods make toward these fundamental needs of the human body. In other words, we must learn to "take foods apart." The science of nutrition seems complicated because the actual nutrients can not be seen as such in natural foods and also because they are very irregularly distributed in foods. We can get a clearer understanding of the matter if we take a set of rods of equal length to

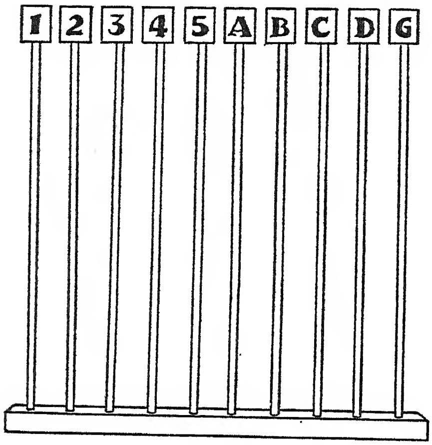


FIG. 1. THESE BARS, ALL THE SAME HEIGHT, REPRESENT 100 PER CENT. OF THE DAY'S REQUIREMENT FOR EACH OF TEN DIETARY ESSENTIALS. 1, CALORIES. 2, PROTEIN. 3, CALCIUM. 4, PHOSPHORUS. 5, IRON. VITAMINS A, B, C, D, G.

represent the day's requirement of each known dietary essential, and then use this set of "measuring rods" to tell us how far a given food will go toward meeting these requirements. By means of ten rods, each with a card bearing a letter or number, ten dietary essentials can be represented, the first five in this case indicating calories, protein, calcium, phosphorus and iron; the five with letters standing for five essential vitamins, A, B, C, D and G. All the rods are the same length, to indicate the total daily requirement as 100 per cent. of each essential. Not all the essentials of an adequate diet are represented here; but under most circumstances, by selecting natural foods known to furnish these, the others will be provided when the requirements for these ten are met. So this set of "measuring rods" will serve very well for practical purposes. Now if we wish to learn why advantages accrued to the Masai from high milk consumption we may observe what proportion of each of these required substances would be furnished by a quart of milk. Each card is moved down to a point on the rod which indicates the proportion of the total requirement furnished by the milk as shown in Fig. 2. Now it is quite easy to see why milk is recommended, wherever available, as the best foundation of any diet. It is interesting to inquire what could be obtained from an equal number of calories in the form of a cereal food such as whole wheat. The values for this food are shown in Fig. 3. The deficiencies of a cereal diet are now quite evident, even though the whole grain be consumed. When the bran and germ are removed, cereals contain very little of the so-called "protective" substances required, namely, minerals and vitamins.

By comparing Figs. 2 and 3 it is also easy to see that the cereals and milk can advantageously be combined. The bran and germ of grains are perhaps the greatest source of vitamin B in regions where grains are grown. Likewise, they furnish in readily available form iron and copper in which milk is low. The copper in the cereal aids in the utilization of the iron in the milk. All cereals are very deficient in calcium, hence in the milkless diet of the Kikuyu tribe, there is no good source of calcium except the salt licks and plant ashes, and as these are restricted to mothers and young children, the men and boys suffer most severely for lack of them.

The Kikuyu babies grow about as well

as the Masai babies, or even English and American babies, for the first three months. But their subsequent growth is progressively poorer. This is partly because of the inferiority of their mothers' milk, which reflects the poor quality of their diet, and partly because of the lack of any suitable supplements to mothers' milk available for infants. Nevertheless, it must be remembered that without their mothers' milk these babies would scarcely grow up at all. If there are no animals to convert grass and grain into milk, mothers must perform this task, and it is important that their diet be adequate for the purpose and that they continue to supply milk for several years after their children have begun to eat other foods. For it is now generally recognized that milk is indispensable during the whole period of growth if full development is to be attained. Baron Takaki (who is distinguished for the eradication of beriberi from the Japanese Navy), asked when past 80 years of age and still very vigorous how he accounted for his good health in his old age, replied that he was most fortunate in that, being the only child of his mother, he had the advantage of her milk for seven years. Certainly nothing could be more disastrous for children under five years of age than to deprive them of their mothers' milk without providing them a full equivalent in milk of some other species.

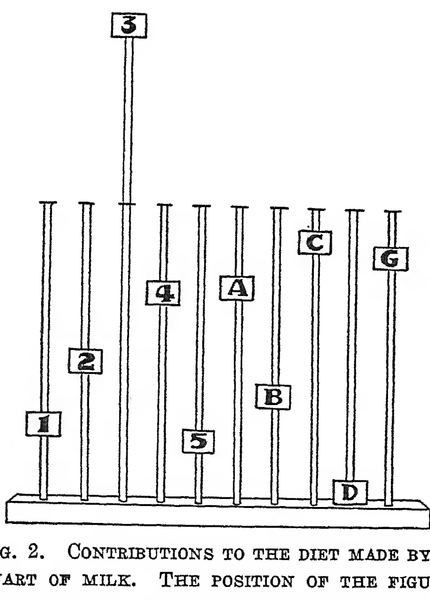


FIG. 2. CONTRIBUTIONS TO THE DIET MADE BY A QUART OF MILK. THE POSITION OF THE FIGURE OR LETTER ON THE BAR INDICATES WHAT PROPORTION OF THE DAY'S REQUIREMENT OF THE GIVEN ESSENTIAL IS FURNISHED BY THE MILK. THE VERY LARGE CONTRIBUTION OF CALCIUM NO. 3 EXPLAINS THE UNIQUE PLACE OF MILK AS A SOURCE OF THIS ELEMENT.

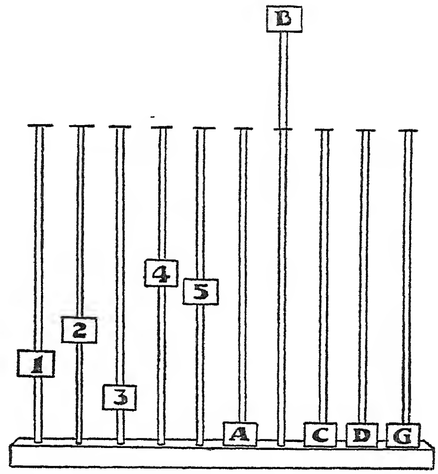


FIG. 3. CONTRIBUTIONS TO THE DIET MADE BY WHOLE WHEAT FURNISHING THE SAME NUMBER OF CALORIES AS 1 QUART OF MILK. THE RICH CONTRIBUTION OF VITAMIN B GIVES THIS FOOD A VALUE NOT ALWAYS APPRECIATED.

In sunny south Africa neither the Masai nor the Kikuyu lack vitamin D. For this reason, whatever calcium and phosphorus either tribe may obtain will be used to its full value for bone and tooth development. The bone diseases, dental caries and arrested growth among the Kikuyu are largely due to actual calcium and other shortages which no sunshine could remedy. They do not suffer from a disease which arises from lack of vitamin D, *e.g.*, rickets, as do children in regions of little sunshine. In the British Isles, rickets has been a scourge for centuries. E. Mellanby, now

secretary of the Medical Research Council of Great Britain, was the first investigator to show that rickets could be produced in puppies by a simple modification of the diet. He fed one set of puppies a ration in which the fat was butter or that in egg yolk and another the same ration, except that lard was the fat used. The development of rickets was prevented by the diet containing butter or egg yolk fat but not by that containing lard. This led to the discovery a little later by McCollum of vitamin D in these fats.

May Mellanby reported in 1931 a study of three institutions in the neighborhood of Birmingham, accommodating over 800 children, 5 to 14 years of age,[7] chosen because of similarity in their diets, "judged by all ordinary standards to be of a thoroughly satisfactory character." Every child cleaned his teeth once or twice daily and dental care was provided. In Institution No. I there was added daily to the regular diet according to age 1 to 1½ ounces treacle (golden syrup). In Institution No. II one group received from 1 to 1½ tablespoons of olive oil and a second group the same amount of olive oil in which a suitable amount of irradiated ergosterol (vitamin D) had been dissolved. In Institution No. III a group received a daily ration of cod liver oil. After two years it was found that while the number of carious teeth had approximately doubled at each of the control institutions, it had increased by only 50 per cent. at the third institution.

In many parts of the United States the regular inclusion of a small portion of cod liver oil or its equivalent for vitamin D is essential for the protection of every child, as the sunshine is not sufficiently abundant, but lack of this vitamin is not a problem of the sunny Southwest, or other regions where the days are radiant for long hours and life is mostly out of doors. In a land of sunshine, if diets consist largely of cereal food and meat, the problems of good bone and tooth development is rather one of securing sufficient calcium, phosphorus and vitamin A. In the museum of Indian relics in Mesa Verde, Colorado, one of the most interesting observations relating to the health of the ancient cliff dwellers is that pyorrhea was a common dental disease. This was probably due, at least in part, to deficiency in vitamin A, whose lack increases susceptibility to infections. Porto Rico is another country where, sunshine being abundant, rickets is almost unknown. Nevertheless, the people are suffering greatly from malnutrition. The children have not enough to eat even to meet their energy needs, and their diets are deficient in almost everything except vitamin D.[8]

In a large country like India, as in the United States of America, great contrasts are found between the diets of different sections. McCarrison, while British medical officer in charge of the Nutritional Research Laboratory at Coonoor, placed 1,000 rats on the characteristic diet of the Sikhs of Northern India, people whose physique is as fine as any in the world. Their diet is very simple, consisting of whole grains ground into flour, butter, legumes, raw carrots and cabbage, a little meat once a week; but they consume large amounts of milk. On this type of diet the rats throve, infant mortality was non-existent and no adults died except from old age. Old people are a problem to the natives, because they live so long.

McCarrison put another thousand rats on a diet characteristic of Central and Southern India. This consisted of cereals and vegetable fats, with scarcely any

[7] Interim Report of the Committee on Dental Disease of the Medical Research Council of Great Britain. Special Report Series No. 159, 1931.

[8] M. M. Eliot, U. S. Dept. of Labor, Children's Bureau Pub. No. 217, 1933.

fresh vegetables or milk. The infant mortality in this rat colony (as among the people in these regions) was very high and diseases of the respiratory, gastro-intestinal and urinary tracts, of the reproductive and nervous systems and of the skin were strikingly frequent. In this diet, there is an abundance of energy-yielding material and sufficient vitamin B to maintain a fair appetite, but there is a great deficiency of calcium, phosphorus, vitamin A and vitamin G, which would explain the prevalence of the types of diseases observed in the experimental animals, whose life had been led in a sanitary environment, so that the disturbances of health were due to diet and not to other factors. The findings are in harmony with what McCarrison says of the people who exist on these inadequate diets: "The general lassitude, lack of famines, plagues, wars, etc., originate as much in poor diet as in political or educational causes. Rice is a cereal of lower nutritive value than wheat in practically every respect except its energy value." McCay[9] states that even under favorable conditions a Bengali coal miner's output of work is little over one fourth of that of the European miner.

The nutritive differences in the diets of different districts in India are strikingly reflected in the growth of young rats reared upon them. On the "Sikh" type of diet their average weight at the age of 80 days was 285 grams, while on the Bengali type it was only 180 grams, and on the Madrassi type, with more rice replacing wheat, it was only 155 grams.

Yellow maize has the advantage of containing more vitamin A than other cereals, but it is deficient in the two or more pellagra-preventing factors which we now associate with the vitamin G complex. Meat-eating peoples get liberal amounts of these factors in the vitamin G complex, but muscle meat lacks vitamin A and is not rich in vitamin B. Pork muscle is an exception, being rich in vitamin B. This probably is the chief reason why poor people in the South, eating mostly corn, fat pork and molasses, do not get beriberi nor xerophthalmia, but do get pellagra. National diets as found in the past, and for the most part at the present time, are in each case an expression of the accumulated experience of the race inhabiting a given territory with regard to sustenance derived chiefly, if not wholly, from products available within the territory. As long as there was no scientific knowledge to guide dietary practices, the nutritional status of the people has been good or ill according to the extent to which the native resources could meet body needs, and provided that social customs and religious beliefs fostered their use instead of preventing it, as in the case of the African Kikuyu making no use of their goats for food. In the Philippine Islands, when they were taken over by the United States a quarter of a century ago, beriberi was rampant because of the wide-spread use of highly milled rice. It was practically wiped out of the army in three years by the substitution of 16 ounces of unpolished rice and 1.6 ounces of dried beans for 20 ounces of polished rice in the daily rations of the soldiers. But the natives could not be made to change their food habits by a military fiat. To-day, in the cities, child welfare stations save many children by teaching the mothers to give them tiki-tiki (rice polish extract rich in vitamin B), but in the rural districts the milling of rice has been perfected to produce the whitest possible rice and there beriberi is still wide-spread. This shows how little man's instinct guides him to an adequate diet!

In a diet where milk is freely used the deficiency of cereals in calcium and phosphorus has no special significance, milk being very rich in these elements, as

[9] Major D. McCay, "The Protein Element in Nutrition," p. 166, 1912.

shown in Fig. 2. Carnivorous animals get their calcium and phosphorus from bones, and herbivora from the large quantities of grasses and other greens consumed. Human children get it from their mother's milk during the period of most rapid growth, and whether they continue to develop well after the period of lactation is over depends in considerable measure on the amount of calcium which their subsequent diet contains. Southern China shows an interesting adaptation in a country where density of population makes milk-production extremely difficult. Hoh, Williams and Pease[10] have shown how the Chinese custom of cooking bones in the presence of an acid extracts appreciable amounts of calcium. A suitable gift for a prospective mother is a pair of pig's feet. She will hope by the time the baby is born to have accumulated perhaps two dozen pairs. These will help to support her body's demand for calcium during lactation. Older children and adults derive their calcium very largely from green vegetables, of which enormous quantities are consumed. Adolph and Wu, in making a diet to correspond to that used in Shantung province,[11] estimated 30 grams of cellulose as representing a man's daily consumption, an amount which Americans would find almost impossible to consume. This cereal-green vegetable diet is able to induce good bone and tooth development only when the body has an abundance of vitamin D made by the play upon the skin of brilliant and constant sunshine. In Northern China, osteomalacia, the disease of adults of origin similar to rickets, is endemic, owing to the combination of a diet consisting chiefly of cereals with an indoor habit of life. The women are most disastrously affected, as they are housed most closely, but opium smoking frequently keeps the men indoors too.

Nutritional handicaps are often accepted as a part of the race tradition. Classical European paintings show goiter in the most beautiful madonnas. In the past, in Switzerland and in France, cretins numbered hundreds of thousands. Now, thanks to the demonstration in 1917 by Marine and Kimball in Akron, Ohio, of the effective prevention of goiter by the administration of iodine to school children, there will never be such a development of the disease in our goiter belts. As a result of this study its incidence in Switzerland was altered from about 87 per cent. in 1918 to 13 per cent. in 1922. The best protection, in regions where plants and water do not furnish enough iodine, is usually the household use of iodized salt.

Diets not strictly lacking in any one essential may still be far from optimal for pregnancy, lactation and the growth of the young to full maturity. It is the common experience of nutrition laboratories that earlier maturity, greater size and vigor and deferred old age result from diets liberally enriched with minerals and vitamins. Such enrichment is more easily accomplished by the addition of milk than in any other way. A striking illustration of this is furnished by a study of four years' duration, made on English school boys by Mann.[12] The boys, 6 to 11 years old, were receiving a diet supposed to be adequate, but as they were under average weight and height for their age, various additions were made to their diet. The supplements were extra sugar (3 oz.), butter ($1\frac{3}{4}$ oz.), water cress ($\frac{3}{4}$ oz.) or milk (1 pint). With the exception of water cress, these additions were equivalent in calorie value. Mann says of the out-

[10] P. W. Hoh, J. C. Williams and C. S. Pease, *Jour. Nutrition*, 7: 535, 1934.

[11] W. H. Adolph and Mao-Yi Wu, *Jour. Nutrition*, 7: 381–394, 1934.

[12] H. Corry Mann, Med. Research Council of Great Britain, Special Report Series, No. 105, 1926.

come of this study: "The nutritive value of a diet which was originally chosen with every regard for the welfare of the children to be reared upon it could be strikingly improved by additions which in a quantitative sense were small. It is startling to learn, as we do now, that the addition of one pint of milk a day to a diet which by itself satisfied the appetite of growing boys, could convert an average animal gain of weight of 3.85 pounds to 6.98 and an average rise in height from 1.85 inches to 2.63."

Another striking demonstration of the value of a better diet for children was made in six industrial centers in Scotland and Belfast, Ireland. A daily portion of milk, varying from $\frac{3}{4}$ to $1\frac{1}{4}$ pints, was served to 1,400 children attending the elementary schools. Similar groups of children serving as controls received a corresponding number of calories in the form of sweet biscuits. In 7 months the increase in height and weight was 20 per cent. greater in the milk-fed groups[13] than those not receiving the extra milk. "In practically every case it was noted that the children receiving milk showed even where there was obviously poor maternal care, the sleekness peculiar to the well-nourished animal. Their hair had a glossy and bright appearance, their nails were smooth, resilient and looked as if polished, general alertness was common to all the children fed on milk. It was gathered from teachers and janitors that the children were much more boisterous and difficult to control." It is worth while to make every effort to get a milk supply, not only for children but also for adults. No other food enhances the nutritive value of the diet in so many ways at once.

Changes in racial habits may be disastrous if the people are living in nutritional equilibrium but close to the margin of safety. Native diets of the Eskimo, consisting largely of the whole animal, whether seal or fish or wild game, eaten mostly raw, and supplemented with eggs, when available, sufficed to maintain them in health. But the introduction of cereal foods (especially white flour) and sugar, diluted the diet, so to speak, as regards minerals and vitamins, with the result that nutritional diseases, beriberi, scurvy, rickets, night blindness, dental diseases and other less specific signs of malnutrition, have become widely prevalent, and it is now necessary to reeducate the Eskimo in order to cure the ills which have come as a result of the inclusion in the diet of foods lacking the nutritive properties of those formerly consumed.

Whole animals, eaten raw, will furnish all man's dietary requirements except vitamin D, which is richly supplied only by fish liver oils. A study of children in Norway belonging to three races, Lapps, Norwegians and Finns,[14] showed that the Lapps, although the poorest, with the lowest standards of housing and sanitation, had by far the least rickets, owing undoubtedly to the large amount (2 to 3 ounces daily) of fish oil which they consumed.

Even in a sunny climate where rickets is a disease seldom seen, a child should not grow up calcium-poor. If there are grazing sheep, there could be grazing goats, and if every child had even one cup of milk daily, this would not only help to guarantee calcium, but also excellent supplies of phosphorus, vitamin A and vitamin C.

The liver of the animal is especially important as a source of iron and vitamins A, B and G, as is shown in Fig. 4.

Mori, a Japanese physician, studying the eye disease prevalent among Japanese children, found it could be cured with chicken livers. This was one link

[13] G. Leighton and M. L. Clark, *Lancet*, I: 40–43, 1929.

[14] J. Kloster, *Acta Paediat.*, 12, Suppl. III, 1931.

in the chain leading to the discovery of vitamin A which not only cures this eye disease, called xerophthalmia, but is most important for the maintenance of a high degree of vigor in all parts of the body. Among the Indian tribes in the southwestern part of the United States, the liver of the sheep is highly prized as a food delicacy, and it is regrettable that sheep livers are not more abundant, for where the country is arid and green vegetables always difficult to obtain, there is danger of a scarcity of this vitamin. The grazing animal stores richly in the liver this important dietary essential. The milk-giving animal also conserves it in the milk fat. The goat, put into the herd of sheep to guide these less intelligent animals, is a splendid milk producer, and should be so treated as to insure maximum yield. Although corn is richer in vitamin A than other cereals, it would require from $1\frac{1}{2}$ to 2 pounds of corn to yield as much as one ounce of liver. A child fed for a number of years his mother's milk will get a good start, and a deficiency of vitamin A will not show externally for so long a time that when disaster comes there is no thought of its connection with the diet. The tendency of the Indians of the southwest to substitute white flour, which furnishes no vitamin A, for corn and to dilute the meager supplies of this vitamin by lard, which also lacks it, will tend to nutritional disaster, just as the Eskimos' substitution of white flour and sugar for whole seals and whole birds, supplemented by many eggs, has resulted in wide-spread malnutrition. White flour can not safely be made a staple in a diet unless butter, milk, eggs, or green vegetables or fish liver oils are taken in sufficient quantities to insure rich supplies of vitamin A, and unless other foods are similarly chosen to guarantee a sufficiency of other vitamins and minerals.

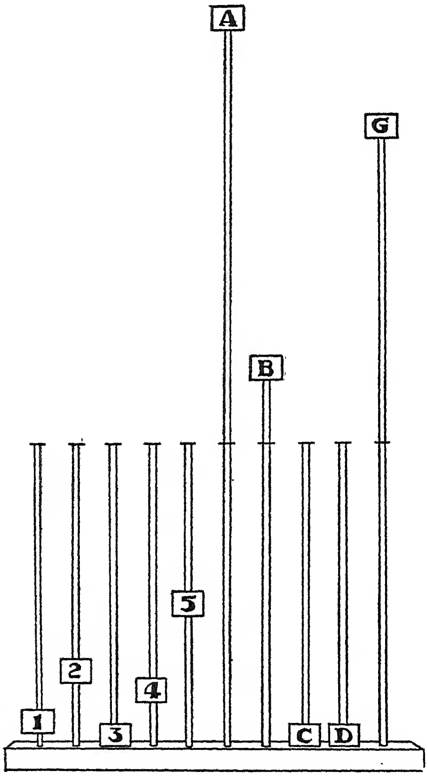


Fig. 4. Contributions to the diet made by 100 calories (2.7 oz.) of liver. The outstanding contributions of vitamins A, B and G give this food a high "protective" value.

Where fresh fruits and vegetables are not obtainable, very large quantities of meat, if eaten raw, will furnish enough vitamin C to protect from scurvy. The meat of the narwhal (the fabled unicorn) is said to be delicious raw, when frozen hard and consequently very tender. The smooth mottled skin is considered a great delicacy, and a frozen square foot is a modest portion. Raw frozen walrus liver served with bits of fat is considered a delectable Eskimo entreé. According to Donald Macmillan,[15] an Eskimo family of four easily consumes four thousand pounds of meat a year, about half of which is eaten raw or frozen. On this diet, the Eskimo is supplied with sufficient vitamin C to escape scurvy.

[15] Donald B. Macmillan, *Am. Museum Jour.* 18: 161–176, 1918.

Stefansson in his Arctic expeditions has given evidence that full-grown men can subsist for long periods on a meat diet without scurvy. But in warmer climates, as raw meat may not be safe from infection or parasites, it is better not to depend upon it for vitamin C, because it is easy to get this vitamin from plant sources. Canned tomatoes are almost universally available and popular, and 1 to 2 ounces daily will protect any normal person, child or adult.

The science of nutrition has not only revealed dietary factors of unsuspected value for health but has given a new concept of the connection between diet and health. Understanding better the contributions which different kinds of food make to the diet as a whole we are able to choose more intelligently and thus to avoid the evils which so often result from the blind following of inclination. Moreover, we now have the power of ameliorating the evils of poverty by such simple protective measures as the liberal use of milk, tomatoes, cod liver oil, green vegetables and whole grain cereals. As Sherman[16] has so aptly said, "The longer lease of healthier and more efficient life which the newer knowledge of nutrition offers may be of very far-reaching significance to human progress, in affording fuller opportunity for the use and enjoyment of the accumulated and ever-growing body of knowledge, through education, association, and social inheritance."

Interest in the dietary customs of different nations and their influence upon health has been greatly stimulated of late by the Health Organization of the League of Nations. For the past 10 years the league has been engaged in such a study, but within the last few years fresh impetus has come from the economic crisis. An extensive report by Burnet and Aykroyd,[17] after visits to different countries to study their nutritional problems and the measures being taken to improve their health through better feeding, has just been published. Special conferences of experts have been called and others are planned to help bring about "marriage of agriculture and public health" through a better understanding of the nutritional needs and how to meet them. A special committee, including agriculture, economic and health experts, met in Geneva in February, 1936, and is preparing an extensive report for the next assembly.

[16] H. C. Sherman, "Food and Health," p. 205, Macmillan, 1934.

[17] Et. Burnet and W. R. Aykroyd, *Quart. Bull. of H. O. League of Nations.* IV: 2, June, 1935.

FATHER NILE AND EGYPTIAN AGRICULTURE

By Dr. W. O. BLANCHARD
PROFESSOR OF GEOGRAPHY, UNIVERSITY OF ILLINOIS

A Desert Oasis

Superficially, Egypt covers a vast territory, almost as large as France and Germany combined, but the real Egypt, the land upon which the Egyptians actually live and work, is but a tiny part, less than one twenty-fifth of the whole. A vast desert of sand and gravel, unproductive and uninhabited, but stretching across it, a long, thin thread of green, a garden, intensively cultivated and densely populated—this latter is the true Egypt. It is the world's largest oasis in the world's largest desert.

Here, on this wonderfully fertile flood plain, life was protected on all sides by great deserts, fertilized and watered by the never-failing Nile, and stimulated by the alternate productive and unproductive seasons, as determined by the rise and fall of that river's waters. Here in this favored spot grew up a great empire with an advanced civilization at a time when Europe was a wilderness. To-day it is the home of some 14,000,000 people, practically all of whom live within sight of the river; all are directly or indirectly dependent upon agriculture; and for all, the waters of that life-giving stream are absolutely indispensable.

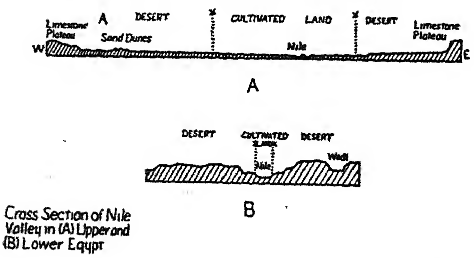


Fig. 1[1]

[1] Data for Figs. 1 and 4 were obtained from H. G. Lyons: The Cadastral Survey of Egypt, 1907. Cairo, 1908, and from H. S. Bey, Under-secretary of State, Ministry of Public Works, Cairo, Egypt, January 11, 1935.

A Land of a Single Resource

Egypt is a land of a single resource—a soil made fertile by Nile silt, but rigidly limited in extent. Minerals, water power, forests, fisheries—these are negligible. But the best soil in the world is useless without water, and Egypt is practically rainless. Alexandria, on the coast, has an annual precipitation of 8 inches, Cairo, 1.3 inches, and south of that city a shower is rare. Under the high temperature and porous soil conditions prevailing throughout Egypt, this rainfall is of negligible importance. The dependence upon artificial watering for the existence of every plant, every animal and every person in the country is both necessary and absolute. Water is the great limiting factor for life in the oasis, and Egypt is "the gift of the Nile" as truly to-day as it was in the time of Herodotus. No other country and no other groups of people of comparable magnitude are so dependent upon a single stream.

The Nile—A Remarkable Stream

The Nile is one of the world's greatest rivers and is in many respects a most remarkable stream.

(1) It is, with the single exception of the combined Missouri-Mississippi, the longest river on earth. From source to mouth it is some four thousand miles, and properly placed it would reach from Chicago to Western Europe. So long is it that it requires some three months for the flood waters to travel from Khartoum to Cairo.

(2) Its source is in Lake Victoria, the

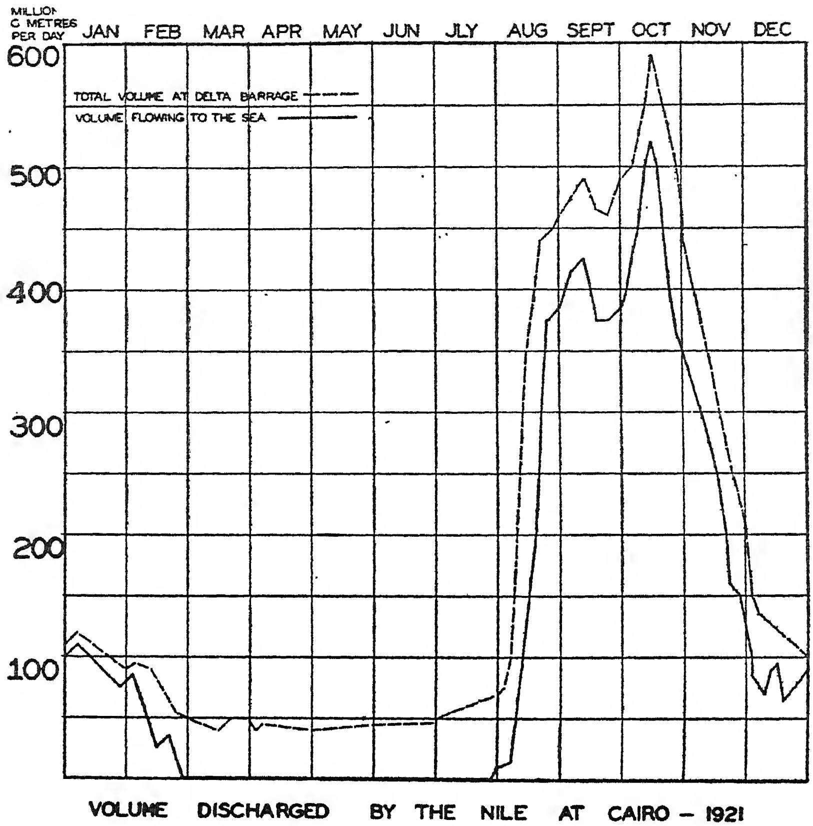


FIG. 2

second largest fresh-water lake in the world, lying at an elevation of three fourths of a mile above sea level in equatorial Africa.

(3) For the last 1,600 miles of its course, it does not possess a single tributary. Indeed so much of its water is evaporated or absorbed in crossing the thirsty desert that only about 3 per cent. of the precipitation over its basin is actually delivered at its mouth. The Mississippi and Amazon discharge about six times that proportion.

(4) It is most remarkable for the height and regularity of its annual floods and for the deposit of rich alluvium which its waters spread over the flood plain.

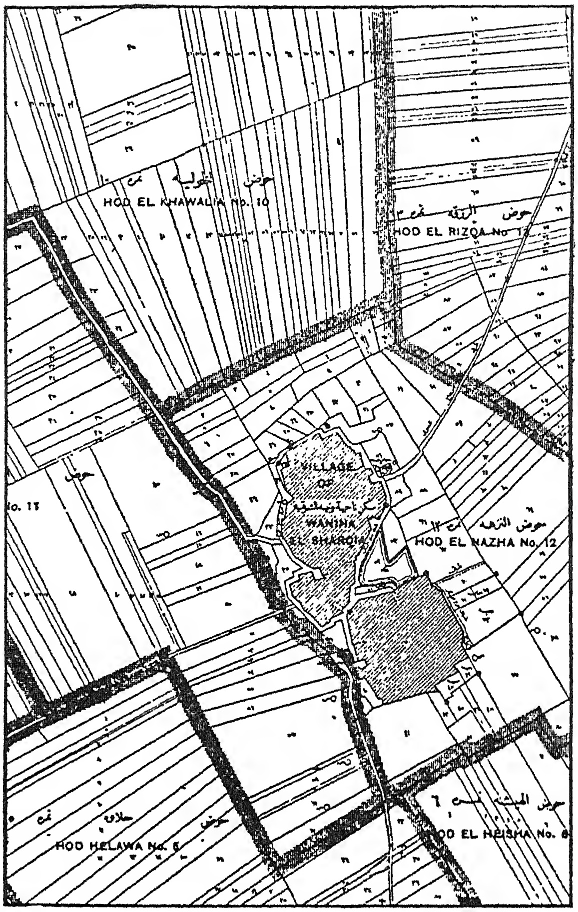
(5) Its long valley flood plain is mostly under ten miles in width, a narrow cleft in a low plateau of sandstone and limestone. It discharges through a large delta, about 150 miles in width and containing about three fifths of all the cultivated land of Egypt (see Fig. 1).

Making the Nile Water the Crops

Irrigation methods, according to the earliest known records, have changed but little down to the twentieth century. This system, commonly called "basin irrigation," operated somewhat as follows:

(1) The flood plain was divided into great shallow basins by low dikes. Seen from above in flood, the landscape suggested a huge checkerboard, some of the diked enclosures containing as much as 50,000 acres.

(2) By autumn, the flood waters, con-



AN EGYPTIAN VILLAGE AND ITS LANDS. 10-YDS.

Fig. 3

tributed by the Abyssinian summer monsoon via the Blue Nile, had reached the lower Nile. A rise of thirty to fifty feet had transformed the river in August and September into a lake. The dikes held the water on the land even after the flood stage had passed. After standing for six to ten weeks, the little water remaining in the enclosures was then allowed to drain off into the low water Nile (see Fig. 2). It is estimated that during this period the average acre absorbed some 4,000 cubic meters of water and had had deposited upon its surface some six tons of sediment. This thorough soaking had to suffice for the moisture requirement of the whole season.

(3) Seeds of quick-growing winter crops, such as grain, clover, beans or peas, were planted in the mud. These grew, matured and were harvested in the spring with practically no rainfall.

(4) After the springtime harvest, the land lay fallow all summer—fields of mud, sun-baked and cracked—until the autumn floods came again and the cycle was repeated.

(5) Certain limited areas too high to

be reached by the normal flood waters or where it was possible to provide summer watering, were irrigated by various primitive devices. Shadufs, Persian water wheels and pumps were worked, often by hand, though sometimes by oxen. A shaduf worked continuously by two men could water about two acres; a water wheel operated by buffalo could take care of eight acres. Some of these are still in use.

This basin system, then, obviously had serious limitations. The amount of land capable of being watered was small, and a failure of the river to rise to normal flood level carried tragic consequences to the high level farms. In 1877, for example, almost a million acres of the higher fields were left dry, carrying starvation and death in its wake. It also meant that as a rule only one crop, a winter crop—a quick-growing crop—could be raised. On the other hand, the limited drain upon the fertility of the land and the film of mud left by the flood waters were sufficient to keep the soil at a high level of productivity for thousands of years.

The new system, called "perennial irrigation," depends upon the great dams and barrages, constructed after the English took charge, especially the Assuan dam. These are opened from July to November, during the normal flood movement, and the land is watered and the crops are planted as under the old basin system. But during the growing of these winter crops the dam gates are closed and the low winter flow, formerly wasted, is gradually stored behind the dams. Then, after the harvest, the stored waters, now at a high level, are fed into a system of canals which irrigate during the summer months. Thus, instead of one winter crop we now have two or more crops grown, and long season crops grown, such as cotton. This arrangement has the advantage of furnishing water during the hot season when maximum growth is possible. Incidentally, it increases the insect menace by providing food for them all the year through.

Problems

In general, the problems to-day, as in the past, center about the balance of *land* and *water*, on the one hand, and of *population*, on the other. Both these factors are susceptible of a considerable degree of control. However, thus far attention has been centered only upon increasing the food supply; little or no effort has been made to restrict the birth rate. The latter has, in fact, far outrun the means of subsistence. In the past 50 years it is estimated that the cultivable soil has been doubled, but the population has been multiplied fourfold. As a result there are now crowded onto that narrow flood plain some 14,000,000 people, the vast majority of whom are illiterate, miserably poor, hopelessly in debt, almost naked and half starved. A cotton rag, a bowl of corn mush and a few dung cakes (for fuel) constitute the sole reward for the daily toil of millions. One hesitates to say they are "making a living"; rather, they are "eking out a bare existence."

How closely the population presses upon the food supply may be appreciated by computing the size of the individual holdings. For many years, the average number of acres per land-owner has decreased until it is now less than two and a half. But this average does not reveal the real situation. That is still worse.

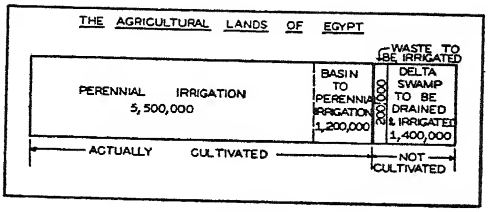


Fig. 4

Forty per cent. of all the cultivated land is in the hands of only *one* per cent. of the proprietors. As a consequence over two thirds of all the land-owners average less than one acre each! Some of the holdings are unbelievably small—less than one foot in width (see Fig. 3). These farmers must supplement their income by hiring out to larger landowners. In 1932 on several large farms on the delta the writer was told the average wage for farm hands was about $5.00 per month!

It is obvious, then, that of the various problems confronting Egyptian agriculture, none is more serious, none more pressing, than that of the education of the masses. While Egypt is the seat of one of the oldest civilizations, to-day, over 90 per cent. of the peasants are illiterate. Their farming methods are essentially the same as in the days of the Pharaohs. Above all, this education should include an understanding of the necessity of birth control, of sanitation and of hygiene. Egypt has the highest death rate of any country for which we have statistics, but its birth rate is likewise one of the highest—a terrible waste of human energy.

The second problem, or group of problems, has to do with increasing the quantity and the variety of agricultural crops. What may reasonably be expected in this direction?

It will be seen from Fig. 4 that of the potentially productive area in 1935—some 7,100,000 acres—only 5,500,000 acres were actually cultivated. The difference includes: (1) 200,000 acres of waste in Upper Egypt now not used but to be irrigated; (2) 1,400,000 acres of brackish swamp land on the Mediterranean border of the Delta, requiring both drainage (by pumping) and irrigation.

In addition, of the land already cultivated, some 1,200,000 acres produce but a single crop annually, because of a lack of water during the summer. This is to receive perennial, or year-round irrigation.

All the above proposals presuppose *more* water and in addition a *better regulation* of the supply. More dams and barrages, pumps for delta drainage, a second heightening of the Assuan Dam, together with added canals, are part of the program. Some of these projects will be in the Sudan (English) and others within the border of Ethiopia (Italian) and will involve cooperative agreements with those governments.

One further difficulty of Egyptian agriculture must needs be mentioned here—the need for crop *diversification.* Few countries are so economically dependent upon the production and export of a single commodity as is Egypt upon cotton. It is the all important—almost the only—money crop. Four fifths of the country's export by value is represented by this staple. Thus, with all their "eggs in one basket," price fluctuations of cotton bring prosperity or ruin to millions. Legal restriction of the maximum area which may be devoted to cotton has been the corrective used thus far.

All in all, it seems that the most important factor in the Egyptian environment is the Egyptian *farmer,* himself. No amount of engineering to increase production will permanently improve the economic status of the native as long as the great mass of people persist in breeding up to the extreme margin of subsistence. Every such increase in food supply in the past has been promptly followed by an increase in the number of mouths to be fed. Neglecting to recognize the *human* factor in the equation has simply resulted in a vicious circle and no progress.

FINGERS FOR EYES

THE STORY OF RAISED PRINT

By Dr. RALPH VICKERS MERRY

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THERE seems always to have been among civilized peoples at least a vague realization that the finger should serve as the eye of the blind. We are told that the Egyptians developed a system of knotted strings, the size and relative position of the knots denoting different characters. By passing such a string through his fingers the blind person could decipher words, but it is perhaps questionable how much real reading was done in this way.

The famous Greek poet, Homer, is said to have been blind, and blindness must have been common under the Roman Empire. It is doubtful, however, if either the Greeks or Romans developed anything which could be called a system of reading for the blind.

As might naturally be expected, the Middle Ages saw practically no progress toward the development of devices for tactual reading, but after the Renaissance scattered attempts at the solution of this problem began to appear. During the sixteenth century Lucas in Spain and Rampazetto in Italy cut letters from wood which they were able to recognize by touch, and thus became familiar with the alphabet. Other blind individuals who attained fame as scholars worked out methods of tactual notation to meet their particular needs. For instance, in 1729 Nicholas Sanderson, the celebrated blind professor of mathematics at Cambridge University, developed a tangible system of mathematical computation.

Perhaps the nearest approach to a general system of raised print appeared about the middle of the seventeenth century in both France and Germany. This was the casting of individual movable metal type made either from lead or from tin. These, it was claimed, were readily recognizable by touch and could be arranged to form words, sentences and, in fact, any amount of literature, limited only by the number of type available. This idea, however, was far from being widely adopted, and it is no exaggeration to say that up to the end of the eighteenth century no satisfactory system had been developed to enable the blind to read with their fingers.

Like so many other important discoveries the idea of embossing tangible letters upon paper came about accidentally. Valentin Haüy, a young Frenchman, had been deeply impressed with the miserable lot of the blind of the late eighteenth century. Through his efforts the first school for the blind in the world was opened in Paris in 1784. The task of educating blind children with no means of teaching them to read must have seemed a colossal one, yet Haüy set about it undaunted.

On a memorable day in 1786 one of Haüy's pupils happened to handle some printed sheets which had just come fresh from the press. He noticed that he could decipher an "O" on the reverse side of the sheet produced by the pressure of the type on the "right side" of the paper. He called this to his teacher's attention and Haüy at once seized upon the idea as the long-sought solution of the problem of educating the blind.

It was a comparatively simple matter to set type so that embossed characters in correct sequence could be produced, and the production of books for the blind began. Haüy at first employed the italic or script type which was in common use at that time, including both capital and lower case letters (see Fig. 1). He indulged, however, in a wide variety of trial and error experimentation, including the variation of the size of characters from very small to very large, and also

the use of practically every kind of type known at the time.

Two theories dominated Haüy's experiments in the field of raised print. The first of these was that the blind must be educated through means identical with those for the seeing but translated into a tactual medium. Thus, he believed that a system of tangible print must be essentially the same as the print used for visual reading. This is shown by his insistence upon the use of both capital and lower case letters and in his relatively strict adherence to regular type form. His second theory was that a positive relationship existed between size and tangibility. That is, the larger the size of the letter the more easily it could be recognized by touch. Both of these theories have proved to be erroneous, yet the first one especially dominated the education of the blind for many years and, as we shall see, its influence is still to be found. Nevertheless, Haüy has been rightly called the "father of the education of the blind" since his discovery, accidental though it was, really marked the beginning of genuine education for those without sight.

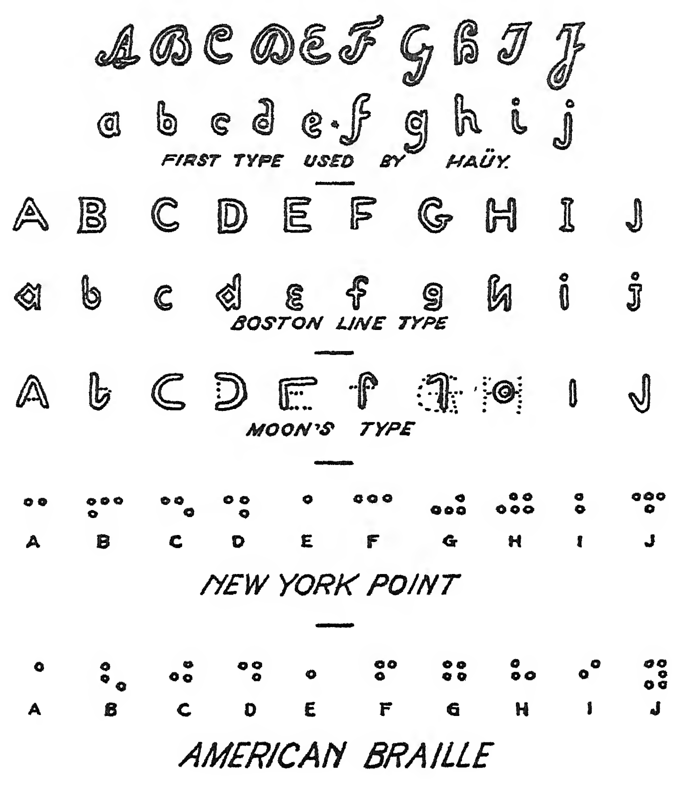
The work of Haüy in France stimulated similar efforts in England and in Germany. After various experiments a more or less modified Roman type was quite widely adopted. James Gall, of Edinburgh, developed a type based on the Roman forms, but with curved lines eliminated, believing that sharp corners increased tangibility. In Germany attempts were made to heighten tactual legibility by outlining the letters in dots or in serrated form. It is of interest to note here the inception of the idea that dots can be more easily recognized by touch than can smooth embossed lines. The belief, however, that tangible print must parallel visual print, as already noted, prevented the development at this time of an arbitrary system of reading for the blind.

The first book in embossed print to be printed in the United States was brought out in Philadelphia in 1833. The type used was a modification of the Roman alphabet somewhat like a system which had been developed in England. It remained, however, for Dr. Samuel G. Howe, director of the Massachusetts Asylum for the Blind, incorporated in 1829, and which later became the Perkins Institution and Massachusetts School for the Blind, to develop the production of books for the blind in this country. After studying the types in general use abroad he introduced what became known as Boston line letter (see Fig. 1), and for about forty years books in this type formed the principal source of reading matter for the blind in the United States.

As the use of embossed print in the education of the blind both in America and abroad increased, the incontrovertible fact soon presented itself that only a relatively small proportion of the blind could master tactual reading to a degree which made it much more than a "stunt." It was realized that to decipher laboriously a letter or word, and to read with enjoyment and profit were two widely different things, and when the novelty of the idea of reading with the fingers had worn off the relatively small number of blind persons who really could read in the generally-accepted sense of the term was discouragingly small. This led to a search for embossed types of greater tangibility and, what is still more important, to a gradual realization that a strict adherence to standard alphabet forms probably was impossible.

It is singularly fitting that the second great contribution to finger reading came from the school which Haüy had founded. It is significant, also, that this second contribution was made by a blind man who knew from personal experience the difficulties involved in tactual reading. This man was Louis Braille, a pupil in the Paris institution for the blind, who in 1829 produced the system of embossed print which now bears his name (see Fig. 2). He had obtained his

FIGURE 1.



idea from Charles Barbier, who had been working on various point systems of codification, chiefly for military use and not with the specific purpose of developing a system of reading for the blind. Braille based his work upon the theory, already referred to, that the raised dot is superior in tangibility to the embossed line. His system is based upon a "cell" of six points, three points high and two wide. Letters and other signs are obtained by varying the number and position of the dots within the cell.

One feature of his system which Braille considered of great importance was the so-called "principle of logical sequence." According to this principle the first ten letters of the alphabet form the basis of all other letters and signs. Thus "k" is "a" with the addition of the lower left-hand dot in the cell, and so on. Since the French alphabet contains no "w," this letter was missing from Braille's original system. It was introduced later to meet the needs of other languages and, as will be seen, is a "j" with the addition of the lower right-hand dot in the cell (consult Fig. 2). As will be pointed out later this principle of logical sequence has proved to be of no significance whatever, either in learning to read Braille or in writing it. This leads us to the second and most important contribution of Braille, that is, his system could be written easily by the blind through the use of a specially-constructed slate and stylus. Nothing of this kind had been possible with previously-developed systems of embossed print.

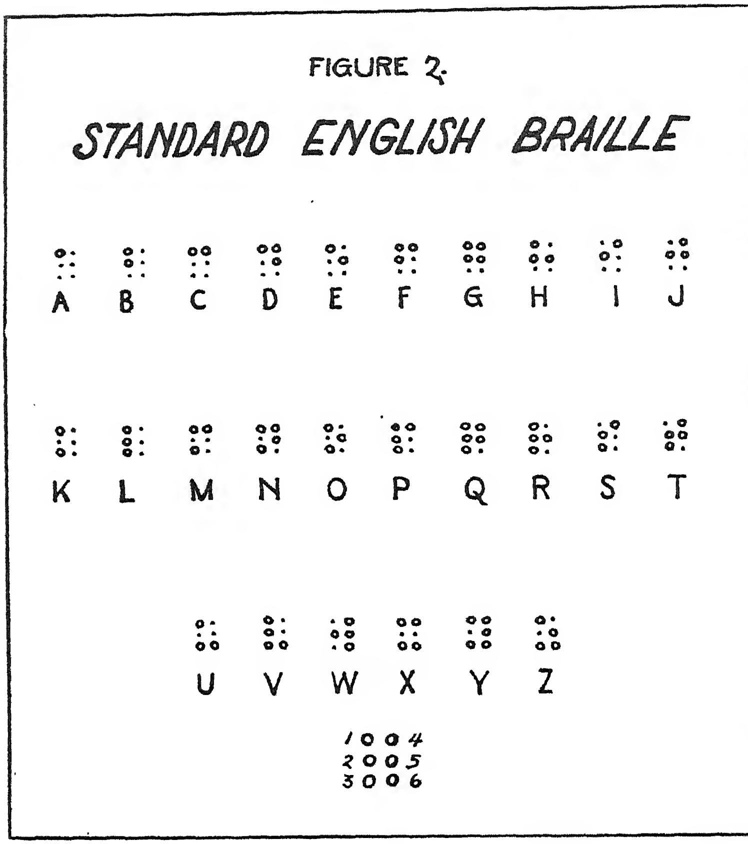


FIGURE 2.

STANDARD ENGLISH BRAILLE

With the many real and apparent advantages of the Braille system one would expect that it would have received immediate and wide-spread adoption. Such, however, was not the case. It was not used in the Paris school until 1834, found its way to England and Germany much later, and did not make its way to the United States until 1860 when it was introduced into the Missouri School for the Blind. The slowness of its progress can be attributed mainly to the persistence of the fallacy that an arbitrary system of reading for the blind was undesirable.

Another factor which undoubtedly hindered the spread of Braille's system was the invention in 1847 by Dr. William Moon, of Brighton, England, of a semi-arbitrary system of raised print, which has since been known as Moon Type (see Fig. 1). In this system the characters are based upon alphabetical symbols but are greatly simplified, and in some instances, purely arbitrary signs are used. Moon Type formed a half-way station between strict adherence to the visual alphabet and the wholly arbitrary system of Braille. It proved much more tangible than any of the "line-letter" systems in vogue at that time, and has been the only embossed type besides Braille to survive to the present day. It is supposed to be particularly well adapted for those who lose their sight late in life, although, as will be pointed out later, the reason commonly advanced for this is without scientific foundation.

American educators of the blind seemed to feel that the Braille system as originally worked out by its inventor could be made more efficient by certain modifications. The most important of these were New York Point (1868) and American Braille (1868) (see Fig. 1). New York Point, so called because of its

invention and promotion by the New York Institute for the Education of the Blind, literally laid the cell on its side, making it two dots high and three wide. By varying the number of dots, especially in the base line, a large number of combinations was possible. The principle of logical sequence on which Braille had put so much stress was abandoned in favor of the principle of frequency of recurrence, by which the smallest number of dots was assigned to the most frequently used letters. This, it was argued, resulted in greater speed of reading and writing.

American Braille, developed at the Perkins Institution, retained the original Braille cell of three dots high and two wide, but used the principle of frequency of recurrence, as can be seen by comparing the sample of American Braille in Fig. 1 with the Standard English Braille of Fig. 2.

By the beginning of the twentieth century the embossed type situation in this country was so chaotic that a committee was appointed by the American Association of Workers for the Blind to investigate the merits of each system and to recommend the adoption of one system for general use. In 1915 this committee, known as the Uniform Type Committee, reported in favor of Standard Dot, a system embodying the seemingly best features of New York Point, American Braille and Braille as originally invented. It was felt, however, that the production of a wholly new system would tend to complicate matters still further, especially since England had adopted the original Braille system, as had Germany and other European countries. The American aim was to agree upon a system which also would be acceptable to the English, and thus make the interchange of embossed books in the English language a comparatively simple matter.

The English had worked out a system known as British Braille Grade 2, which included the original Braille alphabet and a large number of contractions and abbreviations, and word and part-word signs which assist in saving space.

The objection was raised in America that these contractions and abbreviations were too complicated, that they frequently violated the principles of standard literary practice such as syllabication, etc., and were inimical to the teaching of spelling. After considerable discussion a compromise system, known as Revised Braille Grade One and a Half, finally was adopted in this country in 1916–17. This system was fundamentally the same as British Braille, except that about half the contractions in the latter were omitted and certain new rules as to capitalization, punctuation and paragraphing were followed.

This arrangement continued until 1932, when Standard English Braille Grade 2 was adopted both by England and the United States. It represents a practical return to British Braille, except for a few minor details. At last, therefore, after approximately a century of arguing, the system invented by the blind pupil of the school founded by the "father of the education of the blind" came into its own. It is now practically the only embossed type used throughout the entire world with necessary adaptation to meet the needs of various languages.

As one reviews the history of raised print, one is struck principally by the fact that no genuinely scientific approach has been made to the problems involved in tactual reading. Attempts to study the psychology of finger-reading have been few and scattered, those of Karl Bürklen[1] probably being of most significance. Many of the chief arguments for and against certain kinds of type have been based upon assumptions which never were proved experimentally.

[1] Karl Bürklen, "Touch Reading of the Blind" (translated by F. K. Merry), American Foundation for the Blind, Inc., New York, N. Y. 1932. Part I only.

The old fallacy of Haüy that what looked well to the eye must also be suitable to the finger has been responsible for many errors in this field.

For example, Bürklen has shown that there is no relationship whatever between the number of dots in a Braille character and the ease with which it is tactually perceived. The basis of perception, rather, seems to be in the shape of the character, and since Braille consists of a relatively small number of simple forms, confusion between them is responsible for reading difficulty, rather than variations in the number of dots. Reference to Fig. 2 will illustrate this point. For instance, "A" and "G" are essentially block forms, "E" and "I" are diagonal line forms, "D," "F," "H" and "J" are corner forms, while "B" and "C" represent vertical and horizontal line forms, respectively. Other letters and signs are simply expansions or combinations of these fundamental forms. This destroys the main argument advanced by the proponents of New York Point and American Braille, that is, that characters with the fewest dots are easiest to read, hence the most frequently recurring characters should have fewer dots than those used less often. It also vitiates Braille's theory of logical sequence, that is, building the alphabet upon ten simple characters.

The statement so often heard that Moon Type is better suited to the needs of older persons, whose fingers are calloused and whose sense of touch is duller, is hardly consistent with the generally recognized fact that the dot is more tangible than the embossed line. In so far as we can credit data obtained through introspection, the real reason why Moon Type often is learned more easily by older persons has nothing to do with the condition of their fingers. An individual losing sight late in life still retains visual imagery, and all indications point to the fact that tactual sensations are translated into visual images in the process of perception. This rendition of tactual sensations into visual images is, naturally, easier when the tactual materials are closely allied to what the individual has known in visual experience than when the materials are entirely different. As has been shown, Moon Type bears a close resemblance to the visual alphabet, while Braille is entirely arbitrary, hence the person learning to read by touch would find it easier to attach meaning to symbols whose visual images corresponded closely to those with which he had once been familiar rather than to images of symbols which are entirely unfamiliar to him. The dulling of tactual sensitivity through callouses, etc., is to be doubted, since finger-readers of many years have reported that a fairly hard callous develops on the tip of their reading finger without in any way appearing to lessen its sensitiveness. Some individuals, also, can read through several thicknesses of cloth or even with gloves on.

Another fallacious argument has been that the use of contractions and abbreviations decreased the individual's ability to appreciate the material read, or resulted in poor spelling. Such investigations as have been made indicate that not only are Braille letters perceived as wholes, regardless of the number of dots contained therein, but also that entire words are perceived as wholes. Thus, the use of contractions has none of the harmful effects claimed for it, but, on the other hand, increases the speed and thus adds to the enjoyment of finger reading.

Other factors in tactual reading not well understood are the relation of movement to the perception of embossed characters and words; the best size of the Braille cell; the best height of dot and many others. In relation to the first of these it may be pointed out that the essential difference between finger and eye reading is that the former takes place only when the finger is moving over the characters, while the latter occurs during

the pauses made by the eye in traveling along the line. Bürklen studied touch movements to some extent, but, as he himself admits, his apparatus was too crude to permit of any very definite conclusions. The use of the moving picture camera in studying this phase of touch reading undoubtedly would give us much valuable information. The relation of pressure to movement in the process of finger reading is also a problem needing investigation. Bürklen found that in general greater pressure is exerted by poor readers, and these, also, make more random movements.

The customary size of the Braille cell is about 7 mm high and 4.5 mm wide. There is no experimental proof to show that this is the best size to use. In fact, there are indications that a smaller cell would not only save space, but also would increase facility of reading. The problem of space is an important one in embossed printing. For example, the ordinary ink-print edition of a certain book measures $8\frac{3}{4} \times 6$ inches with a thickness of about $\frac{7}{8}$ of an inch. Its cubical contents are roughly 46 cubic inches, and it contains 243 pages of 11-point type. The Braille edition of this same book comprises three volumes 11×11 inches and about $2\frac{1}{2}$ inches thick each. The total number of pages in the three volumes is 547 and their total cubical contents are $877\frac{1}{4}$ cubic inches. Thus we see that in this case the Braille book is a little more than 19 times the size of its inkprint counterpart.

One of the most persistent beliefs founded upon the false analogy between tactual and visual perception is in relation to embossed pictures and diagrams. Investigations have shown with a fair degree of conclusiveness that such pictures and diagrams are practically meaningless to the finger-reader, yet printers of Braille books continue to include them at considerable labor and expense.

The foregoing indicate only a few of the many problems related to tactual reading which require scientific investigation. Raised print has been developed very largely by trial-and-error methods, due probably, in part, to the lack of scientific training of those engaged in this field of work and in part to the relatively small number of finger readers as compared to eye readers. Nevertheless, the production of embossed literature in the United States alone has grown to no mean proportions during recent years. Hundreds of Braille volumes are printed annually and more than forty periodicals, including a weekly newspaper, appear regularly. The Federal Government appropriates each year a total of one hundred and seventy-five thousand dollars to aid in the printing of books, and while this is insignificant when compared with huge appropriations for other purposes, it is large enough to merit an effort to spend it to the best possible advantage. The question is being raised at present whether the newly developed "Talking Book," which embodies the principle of recording books upon long-playing phonograph disks, will not eventually eliminate tactual reading. While it is difficult to predict what will happen in this regard, it seems unlikely that the "Talking Book" will ever supplant Braille, although it will constitute a valuable supplement to it. When it is realized that still only about one half of the estimated one hundred thousand blind persons in the United States can read with their fingers, there would seem to be plenty of room for both Braille and the "Talking Book."

The psychology and physiology of tactual reading are almost untouched fields of investigation, and it is to be deeply regretted that facilities for this type of study are so limited. Those who are seeking new fields to conquer in psychological research will do well to turn their attention to this subject, where they may not only discover significant facts concerning the psychology of tactual perception, but also may render important contributions to the practical problems of Braille printing.

FALSE GROUP THEORY

By Professor G. A. MILLER
DEPARTMENT OF MATHEMATICS, UNIVERSITY OF ILLINOIS

FOR many years there has existed a false group theory which has increasingly hindered the effectiveness of the true theory relating to this subject. Some of the most noted mathematicians have contributed towards the spreading of this false theory, as may be seen from a note to F. Klein's now famous "Erlanger Programm" published in the *Mathematische Annalen* (Vol. 43, 1893, page 66), in which it is explicitly stated that a group need not contain the inverse of each of its operators, and S. Lie is here said to have been the first to point out that the existence of the inverse of each operator is not a consequence of the group concept as such when the order of the group is infinite. The group concept was first formulated as a result of the study of ordinary substitutions (permutations) and these obey intrinsically all the postulates of a group except the one which asserts that the set of elements under consideration must have the property that the product of every two of them and the square of every one is found in the set. Hence this postulate alone was somewhat naturally assumed by some of the early workers in this field to embody the complete group concept instead of being only one of the essentials of this concept.

Various terms commonly employed in the mathematical literature, such as algebra and geometry, are used without a clear definition, and this use causes little inconvenience since special subjects of these broad fields are commonly under consideration and it frequently makes no difference whether these special subjects are regarded as algebra or as geometry, but with respect to group theory the case is quite different, since the term group implies a definite concept which has led to an abstract theory of great importance. The development of this abstract theory is based directly on the definition of this concept and would have been entirely impossible if other definitions frequently employed had been substituted for the exact definition. Hence it follows that those who employ a partial definition of the term group convey the impression that they are working along the lines of an important abstract theory which often has very little in common with what they are doing and could not have been developed even partially if the definition used by them had been employed.

A postulate of the group concept which may be regarded as next in importance to the one noted in the first paragraph of the present article is that the elements of a group must obey the associative law when three or more are combined, two at a time, into one. The history of this law in the mathematical literature is very interesting, since it involves a fundamental feature of the history of mathematics as a whole, *viz.*, the remarkable slowness with which some abstract ideas entered into the general literature of our subject. This law seems to have been first given a special name by the most noted Irish mathematician up to the present time, *viz.*, W. R. Hamilton (1805–1865), who is most widely known now on account of his discovery of quaternions in 1843, and whose collected "Mathematical Papers" began to appear in 1931. He seems also to have been the first to emphasize the great importance of the associative law in various mathematical subjects, but A. Cayley (1821–1895) was the first to employ it explicitly in a definition of the term group. He did this in his

first article on group theory which was published in 1854 in the *Philosophical Magazine*.

It is a striking fact that A. Cayley did not continue to include the associative law in his later definitions of the term group. His failure to recognize the fundamental and abiding importance of this law is reflected in the definition of the term group in the recently completed "Oxford English Dictionary" in eleven volumes (1888–1933), which does not refer to this postulate and thus contributed powerfully to the spread of a false group theory among the English-speaking peoples. The lack of clarity along this line is also exhibited in the recent second edition of Webster's "New International Dictionary," since the associate postulate was explicitly noted in the earlier edition of this work but was omitted under the entry of "group" in this second edition (1934). There is, however, an entry in this edition entitled "associative law" under which it is stated that it is a fundamental law of group theory, but nothing is said about the fact that it constitutes a fundamental element of the term group in all the treatises devoted to the theory of abstract groups and is an essential part of the definition of abstract group as employed in these treatises.

It should not be inferred that the English speaking people are the only ones who have been largely led astray by a false group theory which tends to becloud the beginners who are impressed by the many enthusiastic remarks relating to the usefulness of the concept of group in nearly all branches of mathematics, including the most elementary ones. In fact, the present article was inspired mainly by a recent French publication entitled "Premières leçons sur la théorie générale des groupes" by Georges Bouligand, who published about a hundred articles relating to mathematics in important French periodicals during the last quarter of a century and exhibited therein a wide acquaintance with the modern mathematical literature. On page 5 of this volume of 242 pages it is claimed that a group is associated with every mathematical proposition, *viz.*, the group composed of all the modifications of this proposition which lead from one case of exactitude to a new case of exactitude. It is stated on the same page that an illustration of such modifications is furnished when the so-called Pythagorean theorem relating to the squares on the three sides of a right triangle is modified by replacing these three squares by three similar figures which are similarly placed with respect to this triangle.

One of the reviewers of this volume aptly remarked that Professor Bouligand had exhibited therein anew that he was able to wear the mantle of Felix Klein and other reviewers exhibited their delight in following the views expressed therein. The student of group theory may, however, be led to observe that if all these modifications constitute groups what is left of his beloved subject? A theory of abstract groups could certainly not have been developed if all these modifications were to constitute a part thereof. Is it right that those who apparently know practically nothing about this abstract theory should be allowed to dignify their work by a name belonging to a subject which gained a wide reputation by legitimately restricting itself to domains of relatively small extent but of fundamental importance? It must be admitted that much progress in mathematics has been made by calling different things by the same name and it might be argued that some of the most noted names in the history of group theory, such as those of C. Jordan, F. Klein, S. Lie, and H. Poincaré, are those of men who never formulated in their work a definition of the term group which could be used as a basis for an abstract theory of this subject. These men were interested mainly in the applications of group

theory and the subjects which engaged their attention primarily involved intrinsically elements which had to be explicity embodied in an abstract theory of the subject.

What deserves especial emphasis in this connection is that the properties inherent in subjects to which mathematics has been applied have sometimes greatly affected the definitions of mathematical terms. Such affected definitions may be very useful while working on these subjects in view of their peculiar bend, but they are naturally of little value when applied to some other subjects or when they are used with respect to an abstract theory. It might be asserted that if men like Archimedes, Descartes and Newton could do such effective work in mathematics without a knowledge of the associate law in the combination of operations it might be questionable whether the students in our modern schools should be compelled to familiarize themselves with this law, and whether writers of elementary text-books should be criticized for not referring to this law in their effort to popularize group theory in elementary mathematics. A partial answer to this question is furnished by the fact that the modern student of mathematics is taught from the beginning to be more circumspect than his predecessors were and that he is taught early to avoid some of the loopholes which affected adversely some of the work of preceding generations.

It is well known that modern mathematicians experience great difficulties in their efforts to understand each other as a result of the great variety of subjects which have become objects of mathematical invesigation and the diversity of the methods employed therein. Many of these difficulties are a natural result of the remarkable increase in the number of mathematical investigators and the competition engendered by the desire to attain positions of influence and to master difficulties to which wide attention has been directed especially as a result of the rapidly increasing number of periodicals devoted to this subject. It is therefore very desirable that these difficulties should not be augmented unnecessarily by the use of terms with widely different meanings. For instance, there seems to be no good reason why the student of this subject should find in one place, as on page 130 of the volume cited above, the statement that the positive integers with the exception of zero constitute a group when they are combined by multiplication, while he finds in various other places the contrary statement that they do not constitute a group because they do not include the inverses of the operations involved therein.

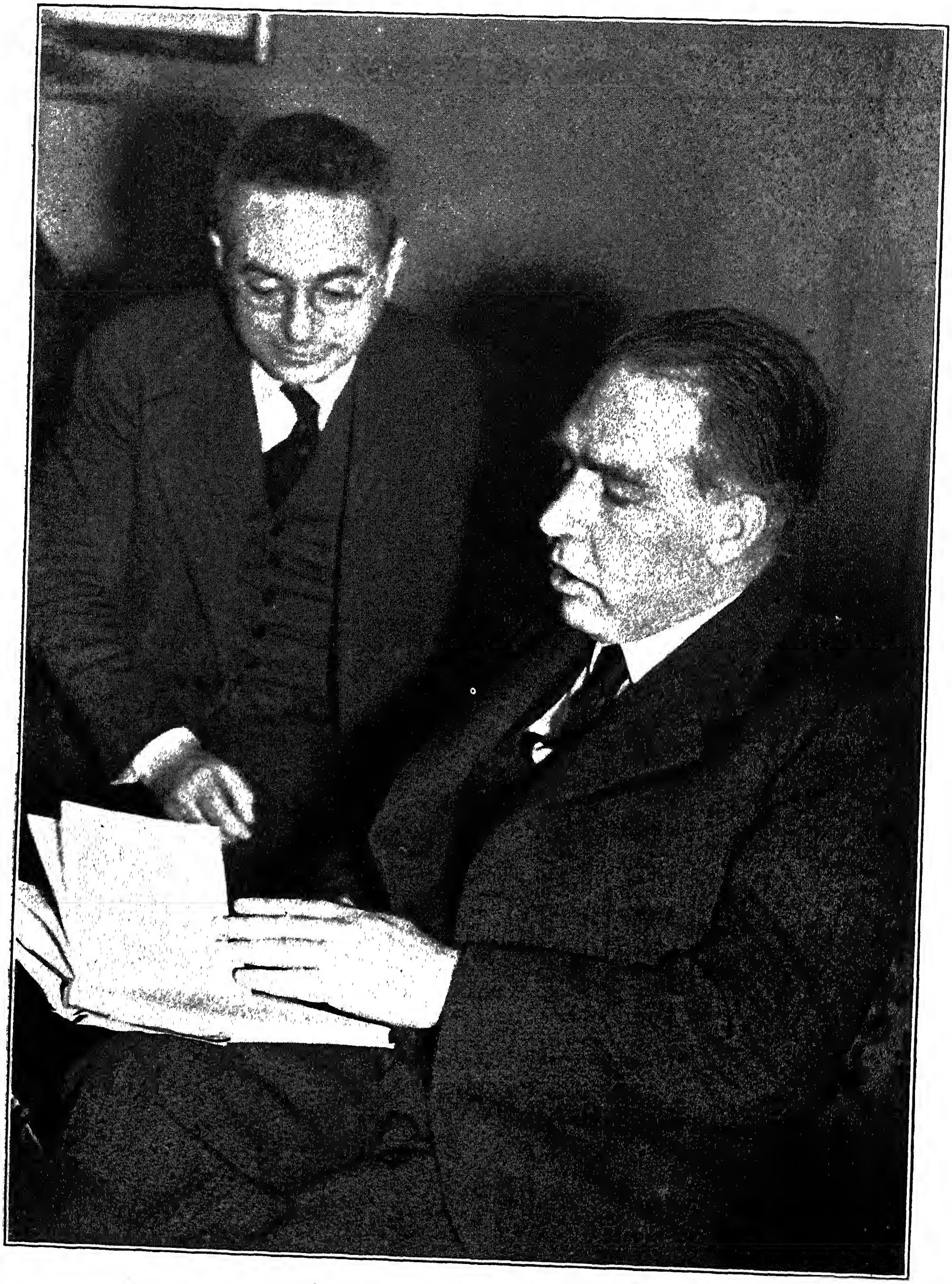
The group postulates to which we referred above are represented by the following continued equation: $(x\ y)z = x(y\ z) = x\ y\ z$. This expresses the fact that every two elements can be combined into one, that the associative law is satisfied when three or more are thus combined, and that only two of them can be combined at the same time. If more than two could be combined at the same time new possibilities would present themselves. For instance, it might be assumed that a product would be affected by the number of the elements which would be combined at the same time. This fact has not been sufficiently emphasized in the treaties on group theory but is obviously of paramount importance in an abstract theory of groups. To complete the group postulates it is only necessary to add that when two of the symbols of the equation $x\ y = z$ are replaced either by two elements of the set or by the same element of the set then the resulting equation has always one and only one solution with respect to the elements of the set. A number of other equivalent formulations of the group postulates have been given and it is to be expected that there is no general agreement as regards the

best formulation. The applications in view naturally affect the choice as regards wording.

The necessary and sufficient group postulates noted in the preceding paragraph are somewhat exacting and naturally do not appeal to the hasty student who takes little time to reflect on the implications in the various assertions with which he is confronted. A large number of the mathematical operations with which the student becomes acquainted early in his career do not obey all these postulates and it is simply absurd to say that all the modifications of a mathematical proposition which lead from one case of exactitude to a new case of exactitude constitute a group. There are however, also many instances of modifications, such as the permutations of the letters in an expression which do not alter the formal value of this expression. These obey all the given postulates and hence they constitute a group. Such modifications present a rich and fertile field for group theory and it is here where group theory exhibited its wide usefulness long before a formulation of an abstract group was attempted.

There is a wide difference between the popularization of a subject and the popularization of the name of a subject. Efforts along the former line imply a familiarity with the essential features of the subject and hence have educational value, while efforts along the latter line may tend to obscure these features and hence to misconceptions in regard to the real nature of the subject. Researches relating to the modifications of propositions within the range of exactitude are of great value to the student of mathematics, but real progress along this line implies a classification of these modifications with respect to their essential differences and not a lumping of them under a name which applies properly to only a small part of them. The unlearning of misinformation is already an undue burden on the student, and this burden should not be increased by misnomers relating to the more advanced subjects. Such platitudes could not be justified here if the subject to which they relate were not of unusual scientific interest.

Some mathematical readers of this article may be inclined to say that when they desire information in regard to the correct definition of a mathematical term they do not consult one of the large dictionaries noted above, which are objects of just pride on the part of English and American scholars, respectively, but they consult the mathematical works employing these terms. One may, however, be justified in insisting that one should not find misinformation in these dictionaries and in works especially intended for teachers of elementary mathematics as the volume cited above in the fifth paragraph of this article. These facts seem to justify a vigorous protest and an effort to exhibit clearly their adverse tendencies. It may also be of interest to the student of general science to see that in such an exact science as mathematics false gods have sometimes been set up and many have been misled to worship them.



PROFESSOR NIELS BOHR

To the left is Professor Richard Courant, chairman of the department of mathematics in the Graduate School of New York University.

THE PROGRESS OF SCIENCE

PROFESSOR BOHR'S VISIT TO AMERICA

PROFESSOR NIELS BOHR, director of the Institute of Theoretical Physics at Copenhagen, will give the Hitchcock lectures at the University of California at Berkeley during the month of March. He will give a series of public lectures and will hold daily conferences and colloquia. The Hitchcock professorship, endowed by the late Charles M. Hitchcock and his daughter with the sum of $120,000, has been held by a number of distinguished foreign and American scientific men.

On his way to California Professor Bohr gave the first of a series of lectures at American and Canadian universities on January 29 at Washington Square College, New York University, where he discussed "The Problem of Causality." Professor Bohr was introduced by Professor Richard Courant, chairman of the department of mathematics in the Graduate School of the university, who was Professor Bohr's host at a tea in his honor preceding the lecture. The address on "The Structure of Nuclei" which was to be given on the previous day was cancelled because his arrival in New York with Mrs. Bohr and their son Hans on the *Aquitania* was delayed more than a day by a stormy crossing.

Among other institutions which have invited Professor Bohr to deliver one or more lectures during his present visit are Columbia University, the Institute for Advanced Study at Princeton, Harvard University, the University of Toronto, the University of Rochester, Duke University, the Johns Hopkins University, the Carnegie Institute of Technology and the University of Michigan. After serving as Hitchcock professor at the University of California Professor Bohr will lecture at universities in Japan and China on his way back to Europe.

There is hardly a physicist who has exerted a deeper and more constant influence in the development of the physical sciences during the last twenty-five years than Professor Bohr. The great progress in our understanding of the physical behavior of the elements, the periodic system, radiation, photochemical processes and many other things bearing on the structure of matter is definitely linked to the so-called Theory of Quanta. And the whole quantum theory, after Planck's discovery of the quantum of action, has developed under the leadership of Professor Bohr.

Bohr's atomic model of 1912 was only the start. It solved the problem of the spectrum of hydrogen. Soon Bohr's ideas also led to an understanding of the spectra of the other elements; since then theoretical and experimental physics and physical chemistry have been revolutionized on the basis of the quantum theory.

The progress that has been made in this short interval is unequalled in the history of physics. Scientific men of first rank all over the world have participated in the task of investigating the construction of matter and radiation, and recently in particular the construction of atomic nuclei. The Institute of Theoretical Physics at Copenhagen under the direction of Professor Bohr has been responsible for much of the work.

One of the most significant features in the development of the quantum theory, Heisenberg's principle of indetermination, was also developed in this institute. It has become in the hands of Bohr the start for a general philosophical point of view, which can be applied to other fields of human knowledge as well as to physics. These general aspects have led to a limitation in the applicability of the

principle of causality, and are pointing to a similarity between certain principles underlying quantum physics and fundamental phenomena in psychology and biology. This new point of view, called the principle of complementarity, dispels the contradictions which arise in the field of atomic phenomena, and throws light on fundamental questions of psychology and biology.

Born in Copenhagen in 1885, Professor Bohr received his Ph.D. in 1911 at the University of Copenhagen, where he has been since 1916 professor of theoretical physics. He was lecturer at Copenhagen in 1913 and at the University of Manchester from 1914 to 1916. He was awarded the Nobel Prize in 1922; a year earlier he received the Hughes Medal of the Royal Society, London, and was elected a member in 1926. Professor Bohr was made a foreign associate of the National Academy of Sciences in 1925 and is a member of many other national academies.

H. S.

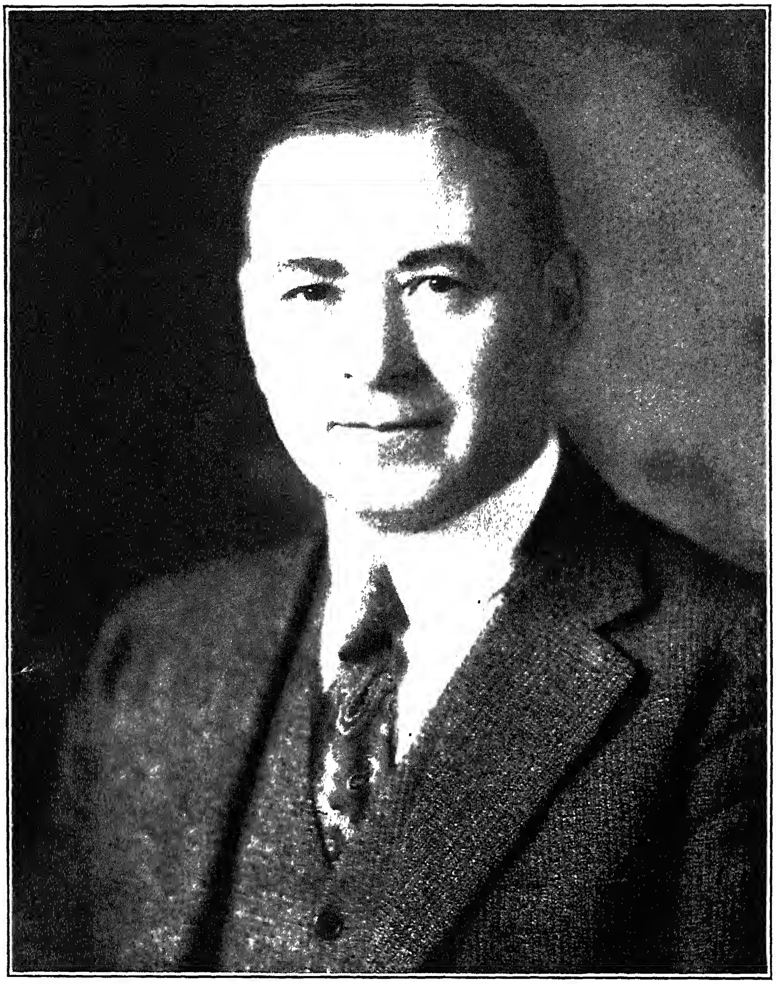
THE PERMANENT SECRETARY OF THE AMERICAN ASSOCIATION, ELECTED AT THE RECENT MEETING

THE American Association for the Advancement of Science has elected as its permanent secretary a distinguished mathematician and astronomer, Dr. F. R. Moulton. It is understood that he will reside in Washington after May 1 and devote his entire time to the work of the association. Dr. Moulton has been long interested in the association, having been a vice-president for astronomy and a member of the executive committee. He has been president of Sigma Xi and a member of the executive council; he is a member of the National Academy of Sciences, having been elected at the age of thirty-eight, the American Philosophical Society and the American Academy of Arts and Sciences, as well as of the Astronomical Society of America, the American Mathematical Society and other American and foreign societies.

Moulton was born at LeRoy, Michigan, in 1872. Shortly after his graduation from Albion College in 1894, he went to the then very youthful University of Chicago and received his doctor's degree, *summa cum laude,* in 1899, his work being in the field of mathematical astronomy. For nearly thirty years thereafter he was a member of the faculty of the University of Chicago, serving through the various ranks to a professorship in 1912. There he had as his associates the distinguished scientific men brought to Chicago by President Harper who included Michelson, Millikan, Moore, Stieglitz, Chamberlin, Whitman, Williston, Hektoen, Jordan, Donaldson, Loeb, Coulter and Dewey.

In addition to many contributions of a purely mathematical character, Moulton explored, in cooperation with his students, the method of periodic solutions of the differential equations of mechanics—a method which was originated by the American astronomer George W. Hill in his theory of the motion of the moon. Hill's method of treating this particular problem was appreciated by the French mathematician, Henri Poincaré, who, bringing to the problem an unrivaled mastery of modern mathematical analysis, generalized and extended Hill's method to a wide class of problems in mechanics. Moulton's work in this field culminated in his classification of the periodic orbits, in the problem of three bodies and in the demonstration of the existence of certain limiting orbits which he called orbits of collision and ejection. His work in this field, together with the work of some of his students, will be found in a large volume, "Periodic Orbits," published by the Carnegie Institution of Washington (1920).

But the work for which Moulton is most widely known is his development, in collaboration with the late Professor



DR. F. R. MOULTON

T. C. Chamberlin, of a theory of the origin of the solar system, of planets and their satellites—a theory that is known as the planetesimal hypothesis. According to this hypothesis the origin of the sun's family of planets is to be found in the circumstances attending a close approach to the sun of some star—a biparental theory, as Chamberlin called it, in contrast with the nebular hypothesis of Laplace, which sought the origin of the planets in the contraction of the sun due to loss of heat and a consequent excessive rate of rotation—a purely monoparental theory.

In 1918 Moulton was appointed major in the army and placed in charge of the ballistics section in the Ordnance Department at Washington. Here he quickly found that the theory of the trajectories of projectiles as developed and used by the armies of Europe was unsatisfactory to an astronomer, who was accustomed to much better methods in tracing out the paths of the planets in their flight about the sun. After all, a projectile is something like a little planet and in introducing astronomical methods into the theory of the motions of projectiles he was not departing very far

from his chosen field of celestial mechanics. After he had retired from the army with the rank of lieutenant-colonel and returned to the University of Chicago, a number of officers from both the army and the navy were sent to the university for several years to be trained by him in the theory of ballistics. Finally (1926) he published his work in this field in a volume entitled "New Methods in Exterior Ballistics."

In 1927 Moulton resigned his professorship and became a director of a large public utility corporation. Notwithstanding his duties in this new field he has found time to write a new text-book on astronomy (1929), a volume on differential equations (1931) and a popular work on astronomy under the title "Consider the Heavens" (1936). He is now contributing to and editing a book on the physical and biological sciences, and he gives weekly broadcasts on all the Columbia network except the northeastern stations.

From 1873 to 1937—a period of sixty-four years—the American Association had (apart from a short interregnum) but four permanent secretaries—Putnam, Howard, Livingston and Ward. They are all biologists. It is appropriate that they should be followed by a worker in the physical sciences distinguished for his contributions to mathematics, celestial mechanics and mathematical physics, with wide interests covering the whole field of science and organization for the advancement and diffusion of science.

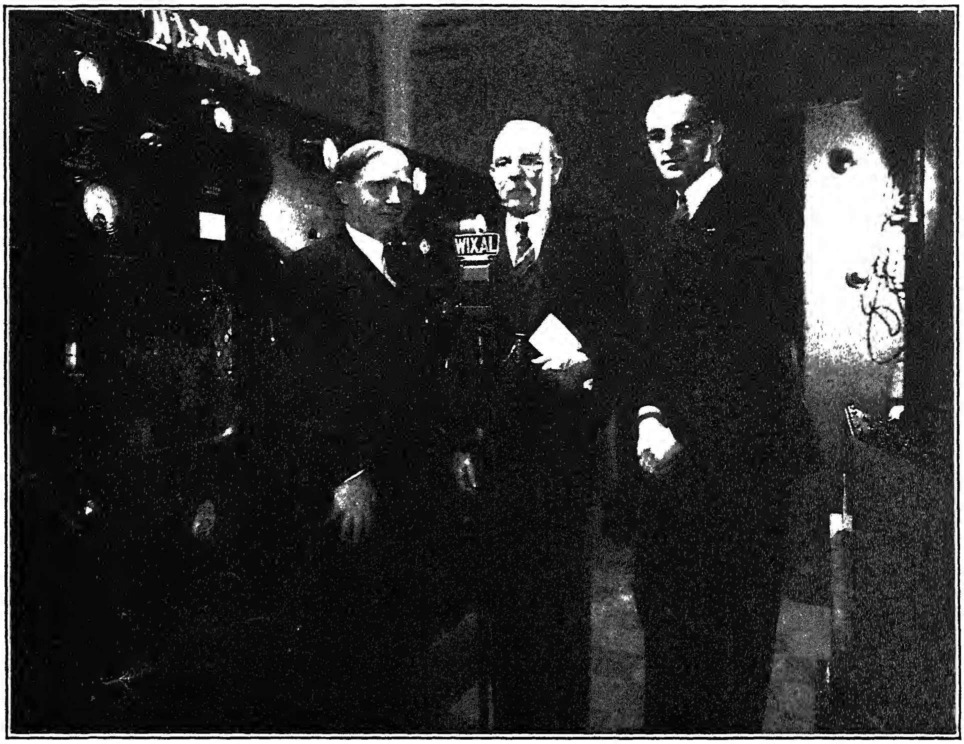
A NEW INTERNATIONAL RADIO SERVICE FOR BROADCASTING COSMIC DATA

A NEW scientific journal, one that is issued by radio rather than with paper and ink, was inaugurated in Boston on February 1 when World Wide Broadcasting Foundation's short-wave station, W1XAL, began daily broadcasts of cosmic data and scientific news. The station in this activity cooperates with the Union Radio Scientifique International, familiarly known in scientific circles by its initials URSI, and Science Service, the institution for the popularization of science. Each afternoon W1XAL will announce in plain English technical data on observations of sunspots, solar radiation, magnetism, ionized layer heights and other phenomena that have been observed in far corners of the world during the same day. The primary purpose of these broadcasts is to make such information available internationally and to interest scientifically inclined laymen in the making of observations.

For nearly seven years Science Service, in cooperation with the American Section of the Union Radio Scientifique International, has collected and distributed daily information about these fundamental inconstants of nature. The Army Radio Net has brought some of this information to Washington, and the Navy has lent its valuable cooperation in the broadcasting of the daily cosmic data messages in international Morse code.

Through arrangements effected by Walter S. Lemmon, radio engineer, who is founder and president of the World Wide Broadcasting Foundation, the facilities of educational short-wave station W1XAL are made available for the extension of the ursigram service in cooperation with Science Service. This station, licensed for international broadcasting on four frequencies, now operates on 20,000 watts and is heard with good volume in almost all parts of the world. The broadcasts of cosmic data and scientific news should, therefore, be available to listeners anywhere who are suitably equipped with standard all-wave receivers. Mr. Lemmon stated this new radio service "will aid world wide cooperation in scientific observation and make more effective the correlation of cosmic causes and cosmic effects."

The Foundation is "dedicated to en-



AT THE INAUGURATION OF THE NEW BROADCASTING SERVICE

LEFT TO RIGHT: DR. HARLOW SHAPLEY, DIRECTOR OF HARVARD COLLEGE OBSERVATORY AND TRUSTEE OF WORLD WIDE BROADCASTING FOUNDATION; PROFESSOR A. E. KENNELLY OF THE ELECTRICAL ENGINEERING DEPARTMENT OF HARVARD UNIVERSITY AND CO-DISCOVERER OF THE KENNELLY-HEAVISIDE LAYER WHICH MAKES SHORTWAVE TRANSMISSION POSSIBLE; AND DR. LORING B. ANDREWS, AN ASTRONOMER AT THE HARVARD COLLEGE OBSERVATORY AND CHAIRMAN OF THE W1XAL PROGRAM DEPARTMENT.

lightenment,'' and in accord with this motto it broadcasts only educational programs, thus endeavoring to give its listeners a broader outlook, a better balanced life in which the deeper needs of mankind are supplied, and fostering international good-will and understanding.

A NEW HIGH VOLTAGE X-RAY PLANT FOR RESEARCH AND THE TREATMENT OF CANCER

A NEW type of x-ray apparatus has been erected at the Presbyterian Hospital in New York City in conjunction with the Institute of Cancer Research of Columbia University, thus combining two activities, the treatment of patients by the hospital and experimental work by the institute.

The design is due to Mr. David H. Sloan, of the University of California. A novel principle which underlies the construction of the apparatus is the use of powerful radiofrequency transmitting tubes to set up oscillations of some 50 meters wave-length in a single turn primary and then inducing in a closely coupled secondary of some 12 turns, extremely high voltages. When properly adjusted the power losses between the oscillator tubes and the anticathode output are so low that enormous amounts of x-ray can be generated. As the ratio between the primary and secondary coils is only 1 to 12, it is obvious that the ap-

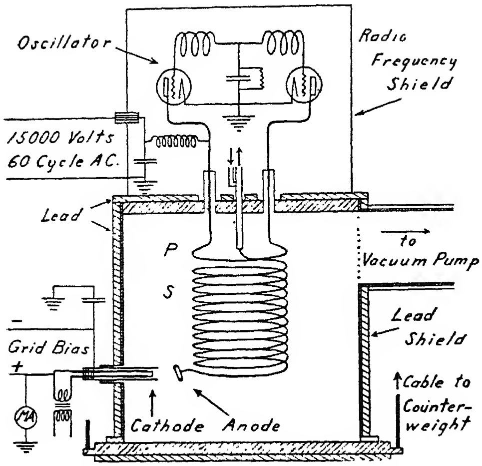
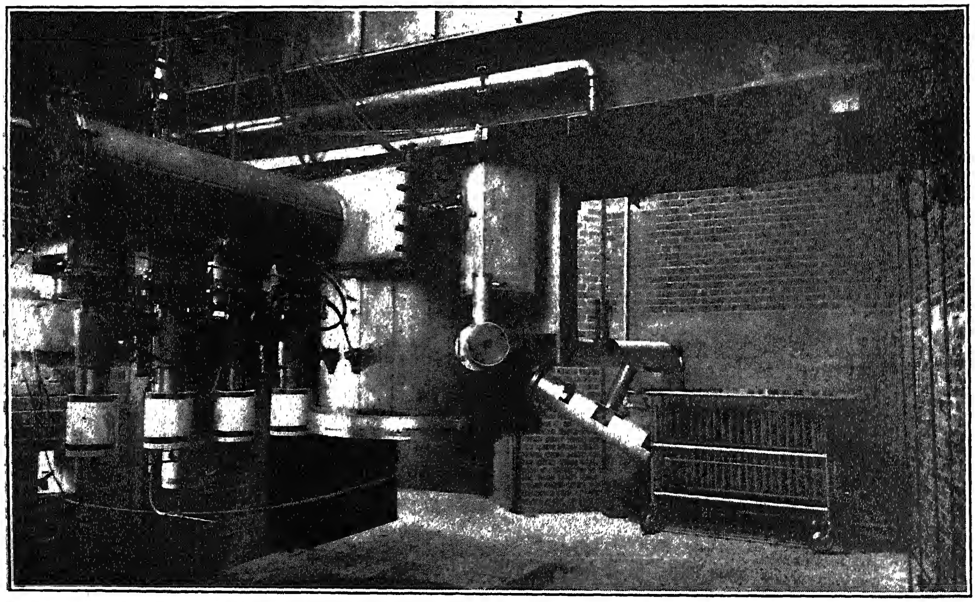


DIAGRAM OF X-RAY APPARATUS

paratus does not act as a simple transformer, but that there are also resonant oscillations between the different turns of the secondary which greatly amplify the voltage ratios between the antenna and the secondary coil.

The elimination of the intense heat produced is a limiting factor in machines of this type. Mr. Sloan believes that 5,000,000 volts could be obtained without difficulty with certain changes in the arrangement. Whether the production of x-rays at this voltage would be effective is a matter to be decided by experimentation. It may be that 5,000,000-volt electrons would busy themselves causing mutations in the tungsten atom rather than in inducing x-rays. As the tank and much of the apparatus are demountable for convenience of repair, occasional leaks may occur, and, unquestionably, despite the large amount of water used for cooling, a certain amount of evolution of occluded gas or of metallic sputtering must take place, especially if there is any arching between the turns of the secondary. To control these conditions powerful diffusion pumps are necessary, a special type of which has been designed by Mr. Sloan. The practical running of the apparatus in the last few months has demonstrated that the pumping system permits the production of an extremely high vacuum, amounting to something of the order of 10^{-6} mm, 1,000,000 volts.

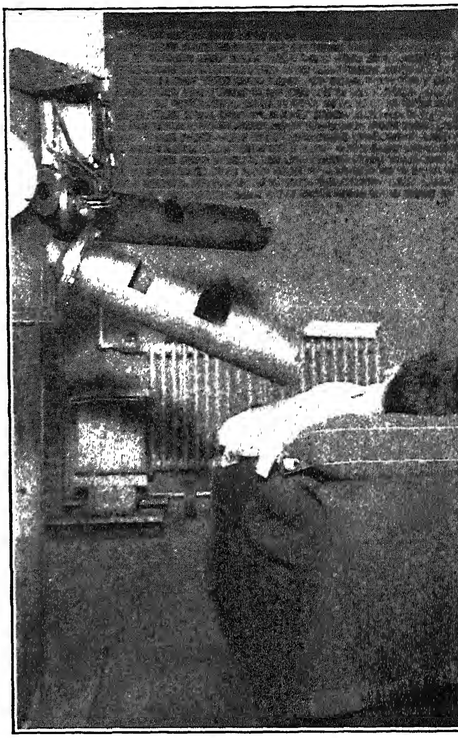
The mechanical construction is relatively simple, as shown in the diagram taken from Mr. Sloan's paper in the



THE HIGH VOLTAGE X-RAY PLANT AT THE PRESBYTERIAN HOSPITAL

Physical Review, volume 47, 1935. It will be seen that the apparatus consists of a power source of about 15,000 volts, single phase, alternating current. This is fed into two generating oscillators of special design, the grids of which are coupled and develop powerful radiations in a short antenna of one turn of heavy copper tubing. The amount of energy which these oscillators must handle is considerable, being of the order of 10 kilowatts. This antenna is suspended in an evacuated stainless steel tank, in which is also hung the secondary, which consists of 12 turns of copper tubing. This carries the anticathode, and through it a large amount of water flows to absorb heat. A filament, which is biased so that only the peak of the wave is used, furnishes the electrons for the target.

The tank, which is swung from steel beams, has five portals, one pointing downward, which is to be used for experimental purposes, and four for the treatment of patients. It is covered with 4 inches of lead for protection from the x-rays.



PATIENT UNDER TREATMENT

The great advantage of the apparatus is, in the first place, its range of voltage, from 200,000 to 1,200,000 volts; secondly, the large current which can be used at the lower voltages. It is possible at 300 or 400 kv. to use 20 or 30 milliamperes, the only limit being the capacity of the water supply for cooling. Such capacity permits the administration of 500,000 Roentgen units through one half millimeter of copper, in a couple of hours, for experiments in which these enormous quantities are important. On the other hand, running at 1,200,000 volts, it will carry 2 milliamperes of current. At these voltages it is possible to see through 1½ inches of lead with the fluoroscope. Five mm or more of lead, therefore, can be used as a treatment filter, and under these circumstances the machine will give 5 Roentgen units per minute at a distance of some 5 feet from the anticathode. The treatment portals are conveniently arranged, as they contain a mirror which reflects the light of a small lamp through the opening in the heavy lead portals which define the x-ray beam. The light is so arranged that it covers the exact area which is to be exposed to x-ray. Thus during treatment the patient can be watched and the exact spot on which the x-ray is reaching the surface of the body controlled. It is proposed to use the machine, at first, to study the Coutard method of treatment with a low rate of radiation and prolonged exposures, obviously, only on selected material, for it is not necessary to use high voltages on superficial tumors.

FRANCIS C. WOOD

THE EFFECT OF EDUCATION ON THE I. Q. OF IDENTICAL TWINS REARED APART

R. C. CATTELL, in a recent article in *The Eugenic Review*, states categorically "that mental capacity is inherited, but that character, habits and skills are largely a matter of the environment." Holzinger in 1929 came to the conclusion from a study of twins that nature and nurture factors have approximately equal influence in determining I.Q. differences. Thus we see that opinions as to the relative potencies of hereditary and environmental factors in determining mental differences vary widely. It is hoped that our study of twenty cases of identical twins separated in infancy will throw some light on this old problem.

The detailed life histories of these twenty cases were analyzed and rated by five independent judges. Their environmental differences were rated numerically from 0 to 10 points, with reference to three categories: educational, social and physical-health. The ratings in all three showed over 90 per cent. agreement for the five judges. These rated environmental differences were then correlated with all measured mental, temperamental and physical differences between individuals of twin pairs. Only seven correlations were high and statistically significant. Five of these were between educational differences and differences in various mental test scores, three between social differences (of a cultural sort) and mental test scores, and one between physical-health differences and differences in body weight. Hence practically the only significant correlations between environmental variance and measured characters concerned mental differences.

The correlations between differences in educational and mental test scores differences were as follows: Binet I.Q., 0.791; Otis I.Q., 0.547; International, 0.462; American Council, 0.57; and Stanford Achievement, 0.908. The correlations between differences in social environment and mental test score differences were as follows: Binet I.Q., 0.507; Otis, 0.533; and International, 0.534. The highest correlations occur in those tests that involve acquisition of knowledge, but the correlation for the International Test, a non-language test, is not much lower than for the Otis test.

It should be noted, however, that most of the positive correlation is produced by a few cases in which the educational difference was great. Without these five cases the correlation is greatly lowered. In fact, if we omit five of the cases having the largest differences in education, the average difference in I.Q. of the remaining fifteen pairs of identical twins reared apart does not exceed that of identical twins reared together.

From this study we may conclude that the I.Q., whatever this may measure, is definitely modified by large differences in education, both of the formal and informal sort. It seems equally justifiable to conclude that small educational differences of one to three years schooling and small differences in social environment do not significantly affect the I.Q.

It is possible with our materials to go one step further and to determine what are the approximate contributions of the different environmental factors in producing the variance in I.Q. in these twins reared apart. Assuming that the influence of a factor on a character is in proportion to the amount of correlation between them, we have calculated for the Binet I.Q. that:

50 per cent. is attributable to educational differences.

10 per cent. is attributable to social differences.

12 per cent. is attributed to joint educational and social differences.

9 per cent. is attributable to physical-health differences.

19 per cent. is attributable to unknown factors.

Similar shares of environmental influence have been worked out for other

mental tests. The detailed report of these studies is now in press and will soon be published by the University of Chicago Press, under the title, "Twins: and the Problems of Heredity and Environment." by H. H. Newman, F. N. Freeman and K. J. Holzinger.

H. H. NEWMAN

ON THE CAUSE OF INFLUENZA

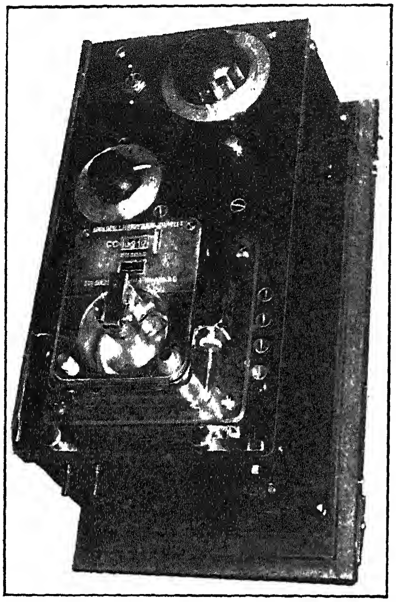
FROM the time of Pfeiffer's discovery of *H. influenzae* in 1892 until the 1918 pandemic, this organism was generally considered the cause of influenza. Work done during and following the 1918 pandemic with *H. influenzae,* however, cast doubt on its causative significance. Evidence was advanced by some investigators at this time that the disease was caused by a filtrable virus. Others, however, were unable to demonstrate that a virus was involved. The question as to the etiology of influenza was, following the work done during the 1918 pandemic, highly controversial.

A disease of swine which appeared supposedly for the first time in 1918 and which because of its marked similarity to human influenza was called "swine influenza," was studied at the Rockefeller Institute, Princeton, N. J., by the late Dr. Paul Lewis and by Dr. R. E. Shope. These investigators found that this disease had a complex etiology; that is, it was produced by the concerted activity of two agents. One of these was a bacterium, similar in all respects to Pfeiffer's *H. influenzae,* the other was a filtrable virus different from any previously encountered. This work suggested the possibility that human influenza might have a similar complex etiology. The thing lacking, so far as the human disease was concerned, was the definite demonstration of a filtrable virus. There was not long to wait for this. In 1933, Dr. Wilson Smith, Dr. C. H. Andrewes and Sir Patrick Laidlaw, working at the National Institute for Medical Research in London, demonstrated that the filtered nose and throat washings from cases of human influenza contained a virus which was capable of infecting ferrets and mice. Other strains of an identical virus were isolated by Dr. Thomas Francis, Jr., of the Rockefeller Institute, from cases of the disease in Puerto Rico and Philadelphia. This new human virus and swine influenza virus were found to cause identical disease pictures in ferrets and mice. The two agents were, however, serologically different. Evidence obtained in neutralization experiments with human sera suggested that the human virus was a wide-spread infectious agent. They further demonstrated that the swine virus had also, at some time in the past, infected man. The theory has been advanced that the swine virus may represent the surviving prototype of that responsible for the 1918 pandemic influenza of man. The swine virus appears, however, to be no longer pathogenic for man, and proof of the theory must await a future pandemic outbreak of the disease. There is no way of telling, as yet, whether human influenza is a pure virus infection or whether, like the swine disease, both the virus and a bacterium are essential to its causation.

A NEW APPARATUS FOR TRANSFUSION AND INTRAVENOUS MEDICATION

ONE of the advances in surgical adjuncts is an apparatus of French manufacture for blood transfusion, slow injection of glucose and other intravenous medication, withdrawal of fluid from a cavity, oxygen injection and prolonged anesthesia. The apparatus is very light, is contained in a wooden box $14'' \times 7'' \times 8\frac{1}{2}''$, is extremely simple, and can be manipulated by one operator.

In blood transfusion it permits direct connection between the vein of the donor



BLOOD TRANSFUSION APPARATUS

and of the recipient without any intermediary other than a flexible rubber tube and hypodermic needles. The blood, which flows continuously, is in contact only with the tube, which is absolutely smooth and of uniform calibre, thus reducing to a minimum the risk of coagulation. The apparatus is so constructed that the accidental reflux of blood from the receiver into the vein of the donor is prevented. The mechanical action which assures the flow of the blood takes place outside the tube through which the fluid circulates. It may be employed for paracentesis (with removal of a large quantity of fluid) and then by reversing the movement of the machine, for injection of medication into the body cavity.

The apparatus is air-tight. Sterilization is not necessary, except, of course, for the rubber tubes. Several successive transfusions can be carried out in a minimum space of time, the only necessity being to have on hand a sufficient number of sterile tubes.

An electric motor causes a roller to revolve which, by pressure on rubber tubing contained in the machine, creates a suction behind it and a compression before it, and assures a continuous progress of fluid as long as the motor is in action. At each revolution, when a medium-sized tube is used (there being three sizes), a cubic centimeter of blood is propelled from the donor to the recipient. Every step may be followed by noting the indexes of the manometers, and the quantity of fluid that has passed can be determined at all times.

When there is no electrical current available, for instance, on the battlefield or in remote rural districts, the apparatus may be manipulated with perfect ease by a hand crank.

The manometers are utilized where the output of the fluid can not be noted visually, as in blood transfusions. These instruments immediately register any accidental obstruction or the reduction of the flow of the fluid resulting from the use of a very fine needle—the suction indicator drops or the pressure indicator rises, according to which is impaired. If the proper speed is maintained there should be no stagnation of the blood in the tube, as the fluid is kept constantly in motion.

By connecting the jack supplied with the apparatus to the terminals of a recording machine, it is possible to obtain a graph recording the quantity of a drug injected into a patient (indicated by the number of revolutions of the pump) as well as the reaction of the heart.

The output of the apparatus, functioning as a pump, may be varied at will from 15/100 cc to 300 cc per minute, according to the size of the tube used and the speed of the motor.

This apparatus of L. Henry and Dr. P. Jouvelet was tested for six months, independently, by the military and the naval authorities of France, and has been adopted by the French Army, Navy and Department of the Colonies.

William Seaman Bainbridge,

THE SCIENTIFIC MONTHLY

APRIL, 1937

FOOLING THE FISHES

FISHING WITH THE BATEAU AND THE WHITE VARNISHED BOARD IN CHINA AND WITH SIMILAR DEVICES IN OTHER PARTS OF THE WORLD

By Dr. E. W. GUDGER

ASSOCIATE CURATOR OF FISHES, AMERICAN MUSEUM OF NATURAL HISTORY

YEARS ago Bret Harte wrote the euphonious lines:

For ways that are dark,
And for tricks that are vain,
The heathen Chinee is peculiar
Which the same I am free to maintain.

It is true that, for devices ("ways," "tricks") that are curious and ingenious ("dark," "peculiar"), the Chinese perhaps excel all other peoples, not excepting Yankee inventors from the "Wooden Nutmeg State." This, westerners have known, since the return from Cathay of Marco Polo (in China and the Orient, 1275–1292) and of Friar Odoric of Pordenone (in China somewhere between 1323 and 1328). Some of the things which we believe new in our day were reported by Marco as old in the China of his day. These things are recorded in the book of Il Milione (so was our old traveler nicknamed in his native city of Venice) and are set out with a wealth of fascinating explanatory notes by Sir Henry Yule in the third edition of his "Marco Polo," edited after his death by the eminent Sinologist, Henri Cordier. Some of these things I have pointed out in an article, "Marco Polo and Some Modern Things Old in the Asia of His Day," in THE SCIENTIFIC MONTHLY for December, 1933.

The Chinese are a fish-eating people, and they have invented more ingenious engines and devices for taking fishes than have any other people known to me. Fortunately these have been figured *in extenso* and described by Pierre Dabry de Thiersant in his quarto volume "La Pisciculture et la Pêche en Chine" (Paris, 1872).

In 35 plates drawn by native Chinese artists, our author shows 120 various devices for taking fishes. These range from a simple hook and line or a trident to the most complicated fisheries engines known to the writer. One of these devices is the ingenious apparatus which is the subject of this article. It will be figured and described in its chronological order.

Neither Marco Polo nor Friar Odoric describes this method of fishing and, since Odoric does describe both fishing with the cormorant and with the otter, it seems probable that this curious device of the varnished board came into use much later than the thirteenth century.

USE OF THE VARNISHED BOARD IN CHINA

When this engine was first used, I can not say. Many of the travelers of the sixteenth century into China recorded

the use of the cormorant as a fishing agent, as I have made known in a previous article (*American Naturalist*, January–February, 1926). I have carefully gone through the works of these early voyagers, but find in none of them any reference to the use of the device under consideration.

The earliest description, which I have been able to find of fishing with the bateau and the varnished board, is from the pen of the Jesuit priest, Louis Le Compte, who went to China with other missionaries in 1685. He speaks of two methods of fishing (the second with the cormorant), and without giving any locality says:[1]

> The first is practised in the Night, when it is Moonshine; they have two very long, strait Boats, upon the sides of which they Nail from one end to the other, a Board about two foot broad, upon which they have rub'd white Varnish, very smooth and shining; this Plank is inclined outward, and almost toucheth the Surface of the Water: That it may serve their turn, it is requisite to turn it towards the Moon-shine, to the end that the Reflexion of the Moon may increase its brightness, [and] the Fish playing and sporting, and mistaking the Colour of the Plank for that of the Water, jerk out that way, and tumble before they are aware, either upon the Plank, or into the Boat, so that the Fisherman, almost without taking any pains, hath in a little time his small Bark quite full.

The next describer known to me is another Jesuit missionary to China, Jean Baptiste Du Halde,[2] who speaks of a "very simple manner of taking fish and one that gives no trouble." Then he describes this curious method of fishing in terms almost identical with Le Compte's and concludes thus: "The fishes playing about easily mistake the color of the varnished board [under the moonlight] for that of the water and throwing themselves on the side of it fall on it and thence into the boat." Though Du Halde gives no details of this fishing, he does more, for he publishes the first figure, found in this study, representing this matter pictorially. In Fig. 1 are shown six boats, each with a japanned board on each side. The fishes are leaping around each boat and are falling into five of them. Two fishermen, instead of being in the boats, are seated on a parapet in the foreground, and one has thrown up a hand in apparent amazement at the scene before him.

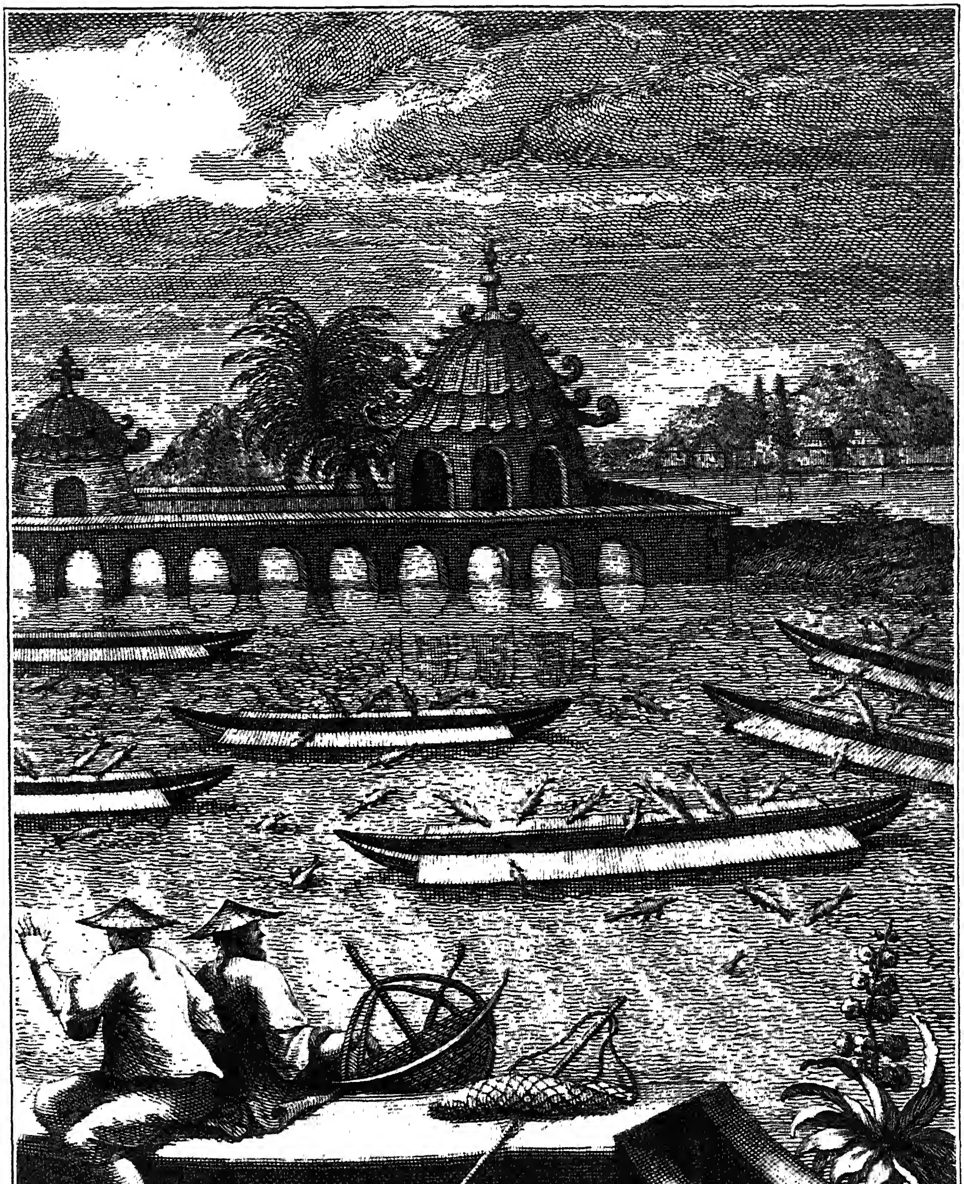
From this time on a legion of travelers in China recount the story of this interesting fishing method, but, unless the writers add curious details or publish figures, their accounts will be passed over since their inclusion would add nothing new. Such details, however, are given in the account next to be quoted.

Not all nights are moonlight nights, even in China, and the catching of fishes must go on, and here is how it was done long ago with the boat and board on dark nights in the then Celestial Empire. In 1771 there was published at London an English version of Pehr (Peter) Osbeck's "Voyage to China and the East Indies" (originally issued in his native Swedish in 1757). On page 316 of this there begins "A Short Account of Chinese Husbandry," by Charles Gustavus Eckeberg, captain of Osbeck's ship. In this Captain Charles Gustavus describes "sampanes with white coloured boards on the sides; and in these sampanes they keep a little fire at night, which makes the fish, which pursue the fire, hop into the sampane." And thus are outwitted a "species of [jumping] fish called mullets, which leap in the dark towards the light of a fire." And ingeniously well conceived is this method of luring mullets, which are everywhere known as broad and high jumpers. Unfortunately no figure accompanies this account.

Next, Sir George Staunton in his "Au-

[1] "Memoirs and Observations . . . Made in a Late Journey through the Empire of China," p. 236. London, 1697. Translated from the original Paris edition, 1696.

[2] J. B. Du Halde, "Description . . . de la Chine," p. 142, fig. to face p. 162. La Haye, 1735. Eng. ed., London, 1738.



After Du Halde, 1735

FIG. 1. FISHING WITH THE BATEAU AND VARNISHED BOARD.

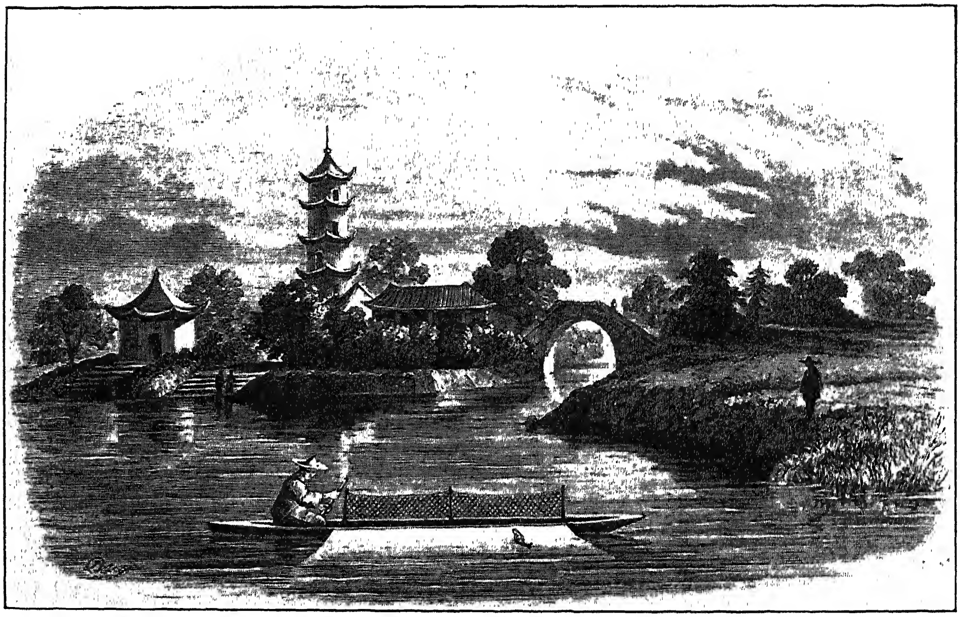
THIS IS THE EARLIEST FIGURE, SO FAR AS KNOWN, SHOWING THIS METHOD OF FISHING. NOTE A BOARD ON EACH SIDE OF EACH BOAT.

thentic Account of an Embassy . . . to the Emperor of China" (London, 1797; p. 398) adds an interesting detail. He describes boat and board and tells us that, "The fish being tempted to leap as on their elements, the boatmen, raising with strings the board, turn the fish into the boat." Unfortunately he likewise gives no figure. Later we shall see such a figure of such a device used in a far distant country.

Further details from an eyewitness are now to be given. Robert Fortune, in his book, "A Residence among the Chinese" (London, 1857, p. 375, fig.), not only gives interesting details of the construction of this curious engine of the fishery, but, unlike the other authors quoted, tells us how he *saw* it work and gives an interesting figure showing an additional device the need for which has probably occurred to some of my readers. Here is what he saw:

> The boats . . . were long and narrow. Each had a broad strip of white canvas stretched along the right side and dipping toward the water. . . . On the other side of the boat a net, corresponding in size with the white cloth, was stretched along above the bulwarks. A man sat in the stern of each boat and brought his weight to bear on the starboard side, which had the effect of pressing the white canvas into the water and raising the net on the opposite side. . . . This will be understood by a glance at the accompanying sketch [Fig. 2]. . . . It was a fine clear night and I could see distinctly the white canvas shining through the water, although several inches beneath its surface. . . . We had not remained motionless above a minute . . . when I heard a splash in the water and distinctly saw a fish jump over the boat and get caught by the net on the opposite side. The object in constructing the boats in the manner described was now apparent. It seemed that the white canvas, which dipped like a painted board into the water, had the effects of attracting and decoying the fish in some peculiar manner, and caused them to leap over it. But as the boats were long and narrow, it was necessary to have a net stretched on the opposite side to prevent the fish from leaping over them altogether and escaping again into the stream. Each fish, as it took the fatal leap, generally struck against the net and fell backward into the boat.

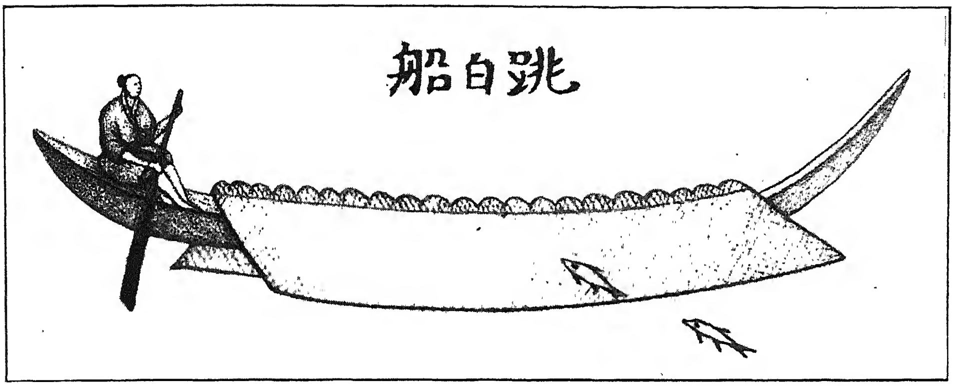
This is an excellent description by a keen eyewitness, but why did Fortune let



After Fortune, 1857

FIG. 2. BOAT WITH WHITE CANVAS AND WITH NET.

THIS IS THE EARLIEST FIGURE FOUND SHOWING A NET TO KEEP THE FISHES FROM LEAPING CLEAR OVER THE BOAT.



After Dabry de Thiersant, 1872

FIG. 3. "PÊCHE AU BATEAU BLANC, TIAO-PÉ-TCHUEN," IN CHINA.

his artist draw the boat (Fig. 2) with the canvas on the side *away* from the moon? And why is this portrayed low in the heavens? Instances of "artistic license," I presume!

The next account adds nothing new, but it is quoted because the author (Le Marquis de Courcy[3]) in true Gallic and gallant style charmingly describes the fishing:

At night when the lucent moon throws its silvery rays on the uncertain ripples, the clever Chinese dispose along the sides of their boats long planks very flexible and painted white, since that is the color most perfectly conforming to that of the waves. Deceived by this perfidious appearance and thinking to play on the surface of the lake, the fish leaps onto the plank and slips into the boat.

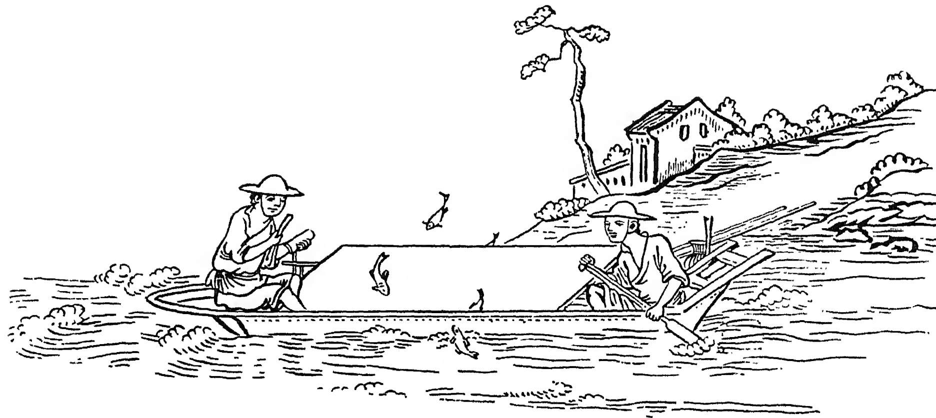
And now we are come at last to the writer (Dabry de Thiersant) whose book[4] led to the collecting and setting out of the interesting accounts quoted in this article. He was for many years French consul in China, and he writes authoritatively of the ingenious device which he calls "Pêche au bateau blanc, *Tiao-pé-tchuen.*"

When, during clear nights in the months of August, September, October, the stars sparkle in the firmament, and when the brilliant moon shines with its lovely light on the calm and limpid waters of the lakes, one perceives, gliding on their surfaces long and very narrow bateaux, nearly level with the water below, and in which at the rear is a man, leaning on his oar, guarding his manoeuvres in dead silence. This man is a fisherman, who has nailed to one of the sides of his bateaux, from end to end at an inclination of 45°, a plank glazed with a shining white varnish and whose upper extremity projects beyond the gunwale some three or four inches. On the opposite side of the bateaux there is set up a net of fine mesh. The fishes, deceived by the mirage, seek to go beyond the plank, which offers itself as a natural obstacle, and fall into the boat. Or, if their *élan* should be too impetuous, they strike against the net, which throws them down into the bottom of the boat. Many fishes are made the victims of this mirage, principally the *pe-yu* (*Leuciscus*), *houang-yu* (*Adelopeltis angusticeps*), and *ly-yu* (*Cyprinus obesus*). This ingenious device permits the taking of fish weighing as much as two and a half pounds, and is employed with the most advantage in waters which are five or six feet deep.

De Thiersant's native draftsman has made a very artistic picture (Fig. 3), but it hardly agrees with our author's text. Fig. 3 portrays a boat shaped like the crescent moon, quite unlike the others figured herein. The "board," here looking like a woven mat, seems to extend to the left gunwale of the boat, where the little scallop-edged fence is shown, and where the other board is attached. Since

[3] "L'Empire du Milieu [Chine]," p. 463. Paris, 1867.

[4] "La Pisciculture et la Pêche en Chine," Paris, 1872, p. 169, Fig. 3, pl. XXIX.



After Gray, 1878

FIG. 4. A FISHING SCENE WITH BOARD AND BOAT IN CHINA.
NOTE POSITION OF BOARD IN BOAT AND THE FISHES LEAPING FROM THE BACK SIDE OF THE BOAT. THE CHINESE ARTIST HAS SHOWN MUCH "ARTISTIC LICENSE" IN HIS DRAWING.

this mat seems to cover the open boat, it is not clear just how the fishes get into the boat. Scientific accuracy and artistic production are not in agreement here.

John Henry Gray ("China," etc., Vol. 2, p. 293. London, 1878) describes an additional device, apparently unknown or unnoticed by other recorders of this fishing method. Here it is:

> Amidships [of the boat, called *Pa-pak-teng*], a stone, which is made fast by means of a cord, is lowered into the water. In the stern of the boat the fisherman sits, and, by means of a short paddle, makes his boat glide along the waters. The course of the boat causes the stone suspended in the stream to make a rushing noise. Terrified at this, and seeing the reflection of the white board, the fish spring towards the latter, and, nine times out of ten, make such a bound as to overleap it and lodge themselves in the centre of the boat.

Gray's figure (No. 4 herein) like de Thiersant's was also drawn by a native artist—who, after the fashion of his fellow craftsman, indulged in considerable "artistic license." The board inclines not into the water but from the offside of the boat into the bottom of the boat at that side near the onlooker, and four out of five fishes seem to be leaping not from the front but from the back side across the contained board into the boat. Perhaps the moon was shining on that side of the boat.

The man in the stern wields the paddle and the boat moves forward, but there is no evidence of a suspended stone. Moreover, there is an undescribed (and uncalled for) fisherman in the bow. What he holds in his hands is not clear. It may be a noise-making device, the like of which will be referred to presently. All that one can say is that Gray's artist was liberal with his "liberties."

Coming down to more recent times, in 1909 Pol Korrigan published in "Chang-Hai" his interesting little book "Causerie sur la Pêche Fluviale en Chine." Pages 117 to 120 of this are devoted to "Les Barques à Miroir" with the figure reproduced as No. 5 herein. He notes that—"We take-larks with a mirror." Then he queries—"Why should we not use it to fascinate the fishes also?" But he adds that "The Chinese have thought this matter out long ahead of us. However, the mirror used by them is not a sheet of glass from Venice, but a white-painted board."

He next states that this method of fishing is practiced sparingly in various parts of China, but most often on that section of the Grand Canal above the

Blue River. However, he found but one board and it is apparently hinged so that in case of rain it might be turned up and made to serve as a roof or cover to the boat.

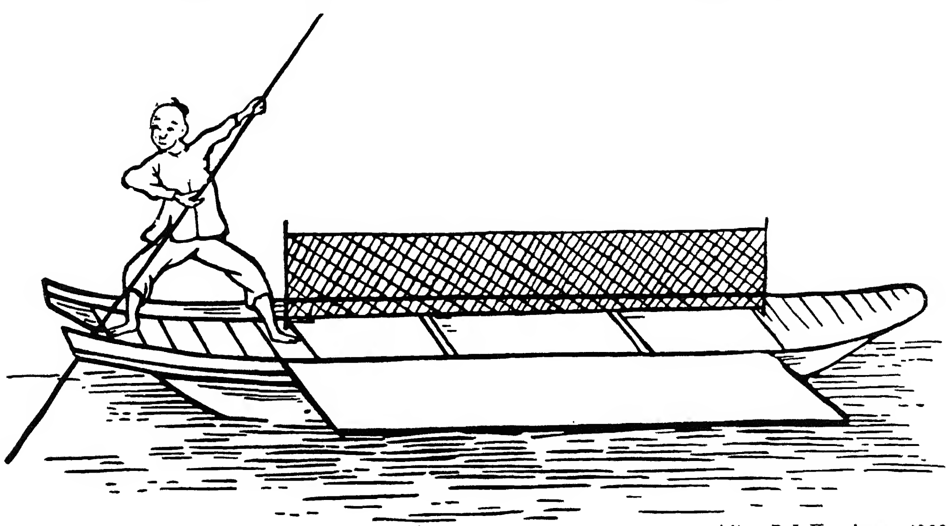
As may be seen in Fig. 5, Korrigan's native artist has portrayed a two-foot-high net set well toward the off-side of the boat. "This is to arrest the leaping fish which in its *élan,* without thought, in a vigorous leap would go beyond the *perissoire* and retomb itself in the river." An exercise which our author naïvely remarks would be "without interest to the fisherman."

Korrigan describes two methods of this fishing. In the first or soundless there is one fisherman "who fixes his barque parallel to the bank of the river with the mirror facing the width of the stream and the light of the moon." The fisherman makes no move, "he seems to be asleep and avoids making even the slightest sound." The fishes then leap and catch themselves as described above.

The other method calls for noise, and its technique is as follows: There are two men: one behind, the sculler; one forward, the noise-maker. The one keeps the boat in motion; the other taps on the planks or on a box made of tin. Thus they advance in the light of the moon. The fishes, frightened, leap "precisely on the side of the plank which shines and so into the boat."

As to which is the more successful method, the author, Monsieur Pol, avowing his ignorance, declines to asseverate, but he sagely concludes that "All roads lead to Rome."

One other figure and statement, and we leave China and the boat with the varnished board. In the *National Geographic Magazine* for September, 1919, there is the interesting present-day photograph (Fig. 6 herein) taken in China by Mr. C. D. Jameson. There is no reference to it in the text, but the caption gives the well-known description and follows with this interesting statement: "On calm bright moonlight nights, the canoe is swung out in the river across the line of an advancing school of fish. The man sits quietly waiting and the fish, dashing at the white board glistening in the moonlight, land in the canoe." This placing of the white board in the path of an advancing school of fish, so that mis-



After Pol Korrigan, 1909

FIG. 5. BOAT, BOARD, NET AND FISHERMAN.
DRAWN BY A NATIVE CHINESE ARTIST.

taking it for moon-lighted water they leap on it and then into the boat, strikes me as the soundest suggestion of how the varnished board really works. Furthermore, it looks as though the cross-pieces of the board or apron in the figure were lashed to the cross-timbers of the boat. If these crude lashings permit, it might be possible to tip the apron up and over to make a covering for the boat as previously noted by Korrigan.

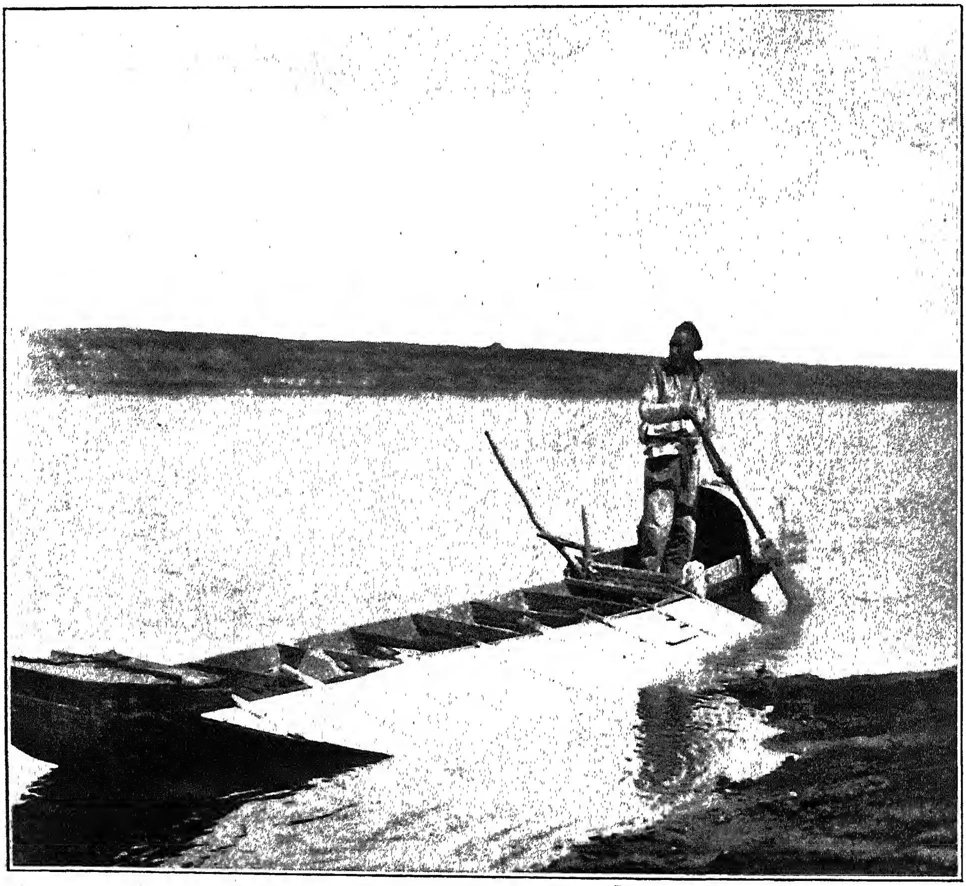
It is very probable that, if other books of travel in China were examined, many other accounts and some other figures would be found. However, I have only given here such as came to my hand in the course of other work.

Use of the Board in Indo-China

Since the Chinese have so thoroughly penetrated into the great peninsula of southeastern Asia called Indo-China, it is to be expected that this method of fishing would be found. According to Day (presently to be referred to) the use of the moon-lighted board is known "in Burmah and the East," but I have been able to find few accounts. Since these records are few, they are grouped under the above general heading, and will be listed geographically instead of chronologically.

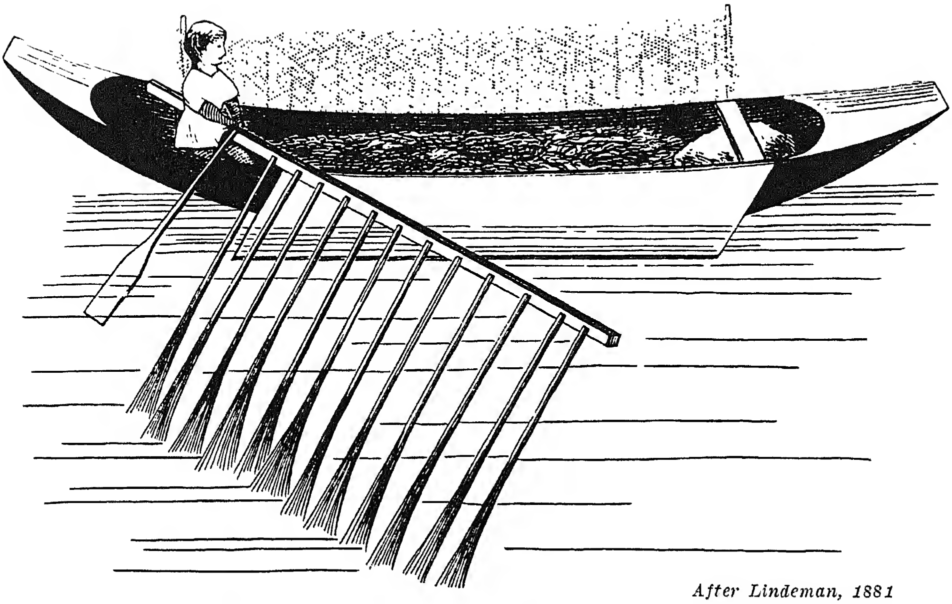
In Tonquin

Here this fishing is carried on at night,



By courtesy of Dr. John O. La Gorce

FIG. 6. BOAT, BOARD AND FISHERMAN–PADDLER.
PHOTOGRAPHED IN CHINA BY C. D. JAMESON.



After Lindeman, 1881

FIG. 7. BOAT AND BOARD WITH IMPROVEMENTS BY THE FISHERMEN OF ANNAM.

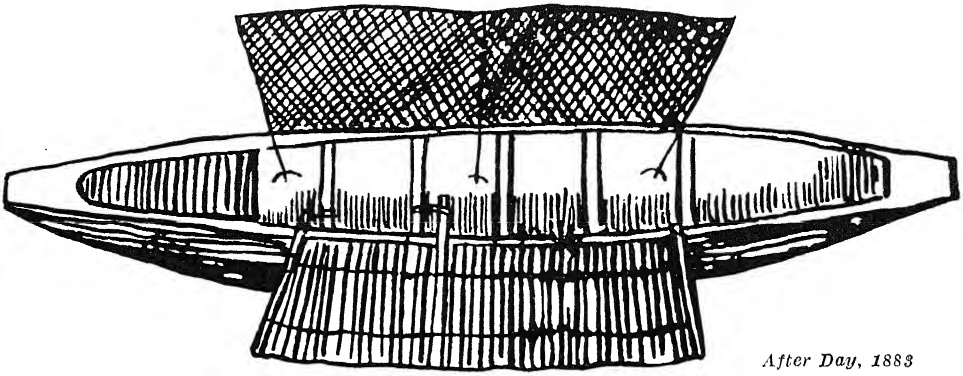
NOTE THE FORWARDLY PLACED STONE WHICH TIPS THE BOAT TO THE RIGHT, THE *Harke* OR RAKE WHICH SCARES THE FISHES SO THAT THEY LEAP ON THE BOARD AND INTO THE BOAT, AND THE BOUGHS IN THE BOAT WHICH KEEP THE FISHES FROM LEAPING OUT.

but instead of depending on the moon to furnish the light, the fisherman carries his own. Thomas Boosey, in his "Anecdotes of Fish and Fishing" (London, 1887, p. 200), states that the fishes are attracted by means of fires toward the boats which have the usual painted boards. These, however, slope downwards (?), and when the fishes fall on them they slide into the boats. It is easy of course to see that this apparatus and its use came from the neighboring China.

IN ANNAM

At the Internationale Fischerei-Ausstellung zu Berlin, 1880, there was a display of fisheries devices from Annam. These were described by H. Lindeman in the *Amtliche Berichte* of the Ausstellung published in Berlin in 1881. On page 244 is shown the interesting "Annamitisches Fischerboot" shown in Fig. 7. The boat, whose native name is *Geh Täh,* is dug out of the trunk of a tree. The fisherman sits in the rear and propels the boat with a short oar or paddle. Forward is a heavy stone, so placed as to tip the boat so that the white board is inclined with its edge in the water. Most remarkable is the apparatus, which Lindeman calls a *Harke* or rake, and which the fisherman apparently controls. This consists of a small beam in which are set 12 rods probably of bamboo. Each of these rods is split at the outer end into from 7 to 10 filaments, hence each is like a hearth-broom. This device as it moves through the water scares the fishes. These leap on the white board and into the boat or in the case of high jumpers possibly against the mat on the back side of the boat. The floor of the boat is covered with boughs into which the fishes fall and out of which they can not leap to escape.

This "Annamitisches Fischerboot" undoubtedly has its origin in the Chinese apparatus, but there are here additional



After Day, 1883

FIG. 8. THE BOAT WITH THE BAMBOO PLATFORM, USED AT CHITTAGONG, INDIA, AND IN INDO-CHINA.

devices, the stone, the boughs and the rake, which go beyond anything that the clever Chinese have invented. This device in Annam is surely an extraordinary fishing apparatus.

IN BURMAH

That the boat and board are used in this country is stated by Francis Day, but he gives no description of this fishing, nor have I been able to find any accounts. He states that the apparatus used is very similar to that figured and described later from India. One wishes for details and for a figure.

From Indo-China we now go first to Java on the East, and then to India proper on the west.

FISHING WITH THE *Lokprauw* IN JAVA

Like the Chinese, the Javanese are a very ingenious people, and like them they get their flesh food mainly from the water. These two factors in the life of the Javanese people have led them to invent some very ingenious fishing devices, among them the *Lokprauw*. This I have found described by P. N. Van Kampen in his "De Hulpmiddelen der Zeefischerei op Java en Madoera in Gebruik."[5]

> The apparatus consists of a small proa, a hollowed-out tree trunk . . . along whose right gunwale a white painted platform is arranged in such a way that its free edge comes into the water. The proa is slowly rowed forth at night. The fish frightened by the bright white color of the platform, spring up and land in the proa. To hinder the jumping out of the fishes and at the same time to act as a counter-weight for the partition, there is arranged on the other side of the boat an obliquely-rising lattice-work. In Krawang the . . . the partition and lattice-work are replaced by a frame of white painted bamboo, slanting down on both sides. In Cheribon and in Djoeana the fish are said to be attracted by fire.

It should be noted that this apparatus is used certainly in the mouths of rivers and possibly out in the open sea. It is to be regretted that Van Kampen does not give more details, and particularly that he does not show a figure of the *Lokprauw*. Whether this device is indigenous to Java, or whether knowledge of it was brought from China by merchants and travelers can not be surely said. But since communication between China and Java has certainly been carried on since the days when Marco Polo and Friar Odoric traveled between those countries, it seems more than likely that this "contraption" of the Javanese is after all of Chinese origin.

THE BAMBOO PLATFORM IN INDIA

Francis Day in writing in 1883 of fishing in India[6] refers to fishing boats and

[5] *Meded. Dept. Landbouw*, Batavia, 1909, No. 9, p. 98.

[6] "Indian Fish and Fishing," Handbooks Grt. Internat. Fisheries Exhib. London, 1883, No. 7, p. 50, pl. 2, fig. 13.

to one (Fig. 8 herein) which is of interest to writer and reader. He says that:

> One curious boat from Chittagong [at the head of the Bay of Bengal, and east of the mouths of the Ganges], but which is also employed throughout Burmah and the East, is fitted with a bamboo platform on one side, behind which a bamboo, having palm leaves attached, projects into the water. The fish are scared, and spring onto the platform, which is partly submerged, and on into the boat, while a net fixed on the opposite gunwale precludes their clearing the boat.

Day's description is not clear nor does his figure (copied as No. 8) clear up the description, but they are given to show that this fishing method has spread to the western edge of the Indo-Chinese peninsula, and, as we shall now see, into Bengal. Apparently the bamboo with palm leaves attached is some sort of device for scaring the fishes—like that figured by Lindeman from Annam. Unfortunately it is not shown in Day's figure.

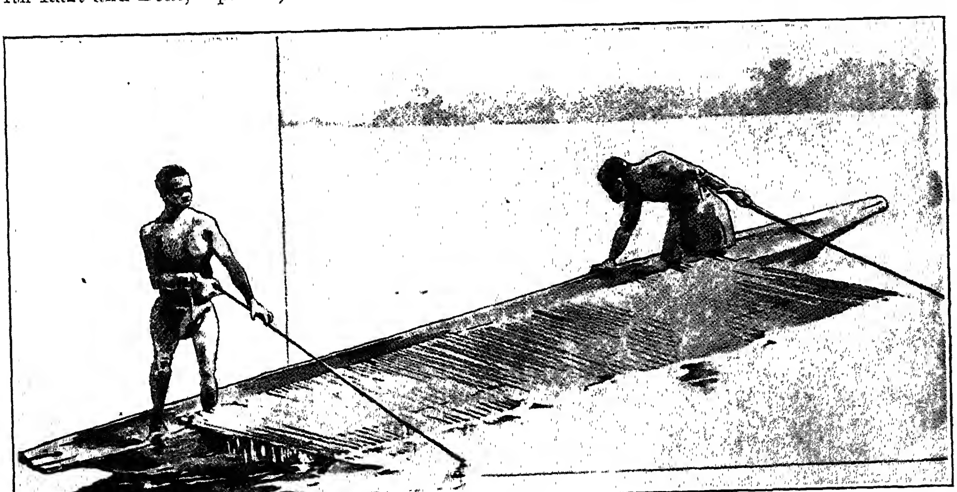
Use of the Mat in India

As late as 1924, James Hornell in describing the "Fishing Methods of the Ganges"[7] tells of the frequent use of floating mats to catch the leaping mullets. Some of these mat-floats have barriers along the edges to confine the fishes that throw themselves onto the float, and some are used in connection with boats but at some distance away. (Devices similar to these mats were once used in other parts of the world, *e.g.*, in Scandinavia, for the same purpose.) One form, however, approximates that which has been described above. Here is Hornell's account of it.

> The most highly elaborated form of this raft-trap is where the raft is much narrowed and attached in a sloping manner along one side of a canoe having this side cut down almost to the water's edge. The raft, which may be 20 feet or more in length, is not more than 18 inches wide, and is supported by a number of transverse bars of split bamboo projecting 8 inches towards the canoe to form a rough hinge arrangement in conjunction with a bamboo pole lashed along the length of the canoe. The mat, made of jute stems, is let down obliquely till its outer margin is a few inches submerged. On moonlight nights, the mullets swimming near, possibly attracted to [it] by the white gleam of the bleached jute stems, get frightened when they come actually against the mat, and try to leap it, only to fall within the canoe.

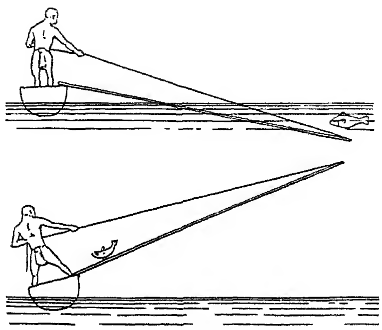
Throughout the Gangetic plain this apparatus is called *chāli* or *chānchi*. In certain districts, Hornell says that the inhabitants specialize in this *chāli* method

[7] *Mem. Asiatic Soc. Bengal*, Vol. 8 ("Fishing with Raft and Boat," p. 216).



After Burrows, 1898

FIG. 9. THE BOAT AND THE MAT USED BY THE NATIVES OF THE CONGO. THE CORDS ARE USED TO LIFT THE MAT UP.



After Burrows, 1898

FIG. 10. FISHING IN THE BELGIAN CONGO.

THE FISHERMAN, PULLING ON THE CORDS, TILTS THE MAT AND THE FISH SLIDES INTO THE BOAT.

in fishing for mullets. Unfortunately no figure is given.

It seems very probable that the inhabitants of southeastern Asia (Tonquin, Annam, Burmah and the Gangetic Plain) learned this fishing method from the Chinese. The Chinese are a far-ranging people, tenacious of their own habits of life, and using in foreign countries those practices which they have found profitable in their home country. Now, however, we go to a faraway country in which the natives have a fishing method almost identical with those studied, but which can not by any stretch of imagination be thought of as having had a Mongolian origin. And yet—!

The Mat in the "Land of the Pigmies"

There are many lands of the pigmies known to the ethnologist, historian and traveler, but that for which Captain Guy Burrows named his book (New York, 1898) is found in the basin of the Congo River in Central Africa. The author remarks that "Fish of all kinds abound in the rivers, and the natives show great ingenuity in catching them." Then without description or explanation of how it works, he illustrates on his page 265 one of these ingenious methods as shown in my Fig. 9. This mat is apparently made up of reeds like those described by Hornell above. How this apparatus is made to work is inferred from the lines fastened to the edge of the mat and of which the inner ends are held by the fishermen. In Fig. 10, found on a preceding page (251) of Burrows's work, is shown how a fish is gotten into the boat.

If the structure of the mat recalls that described for the waters of the Ganges, the work of the fishermen in drawing up the mat and spilling the fish into the boat recalls the action of Chinese fishermen as described by Staunton in 1797. This may be the long arm of coincidence, but how about this statement from Burrows (his page 84)? "The great ladies [of the Mang-bettou tribe] wear the nails of the last three fingers of the left hand very long, to show that they do no manual labor—a custom which, curiously enough, is found at the present day in Southwestern Europe and in China, due to a similar motive."

The parallelism betwixt this fishing method practised in the Congo in 1897, and that used by the fisherman in China at least as far back as 1685—251 years ago—is most remarkable. As the French say, it certainly "gives one furiously to think." However, it seems to me that we have here a fine illustration of the reasoning of Alexander von Humboldt in a study of phenomena having considerable similarity to ours. His words were something like these: "Unrelated peoples in far distant parts of the world under stress of like needs develop like processes and apparatuses to achieve the same ends."

HISTORY AND STRATIGRAPHY IN THE VALLEY OF MEXICO

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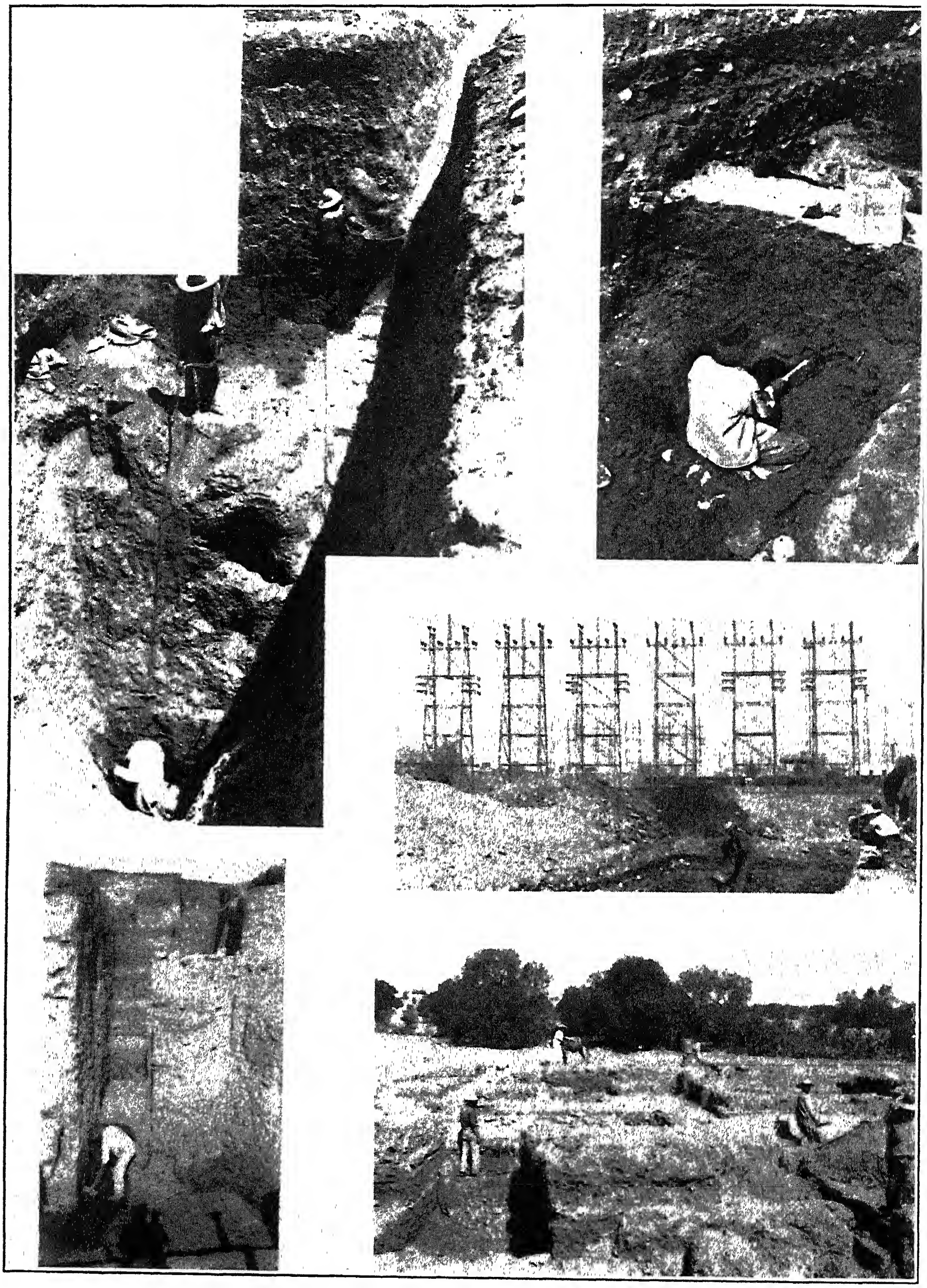
INDIAN Mexico has a past, but not a history. Thousands of mounds are scattered over the country, and in regions suitable for agriculture the plough constantly produces the shattered vessels and tools of vanished people. The modern Mexicans also show their heritage from the past. Thirty-nine per cent. of them are pure Indian, and another 53 per cent. are liberally infused with Indian blood. Even as in Italy, where both the citizens and the land which gives them life bear witness to the background of the Roman Empire, so in Mexico one feels and sees the all-pervading influence of the Indian.

Yet where the Roman past is part of the historical instruction of every schoolboy, the history of Indian Mexico is to most of us a closed book, and even the professional scholar finds that most of its pages are blank. The reasons for the gaps in the historical record are threefold: the Europeanization of Mexico, with the consequent indifference to Indian matters; the conscious destruction of native documents as idolatrous in the days of the evangelization of the country; and the rarity in Mexico of Indian tribes with a knowledge of writing which would enable them to keep historical records.

The history of Mexico, from its Conquest in 1519 to the Revolution of 1910, has emphasized the fortunes of European overlords and their relations to each other and the outside world. The overwhelming Indian preponderance in the population has been by no means balanced by similar representation in the economic and the social world. For four centuries, Europe, with all the guile and brute force of its state and with all the spiritual powers of its church, has striven to eradicate from the Indian all traces of his native culture. Since the Revolution of 1910, there has been a conscious effort to transform the Indian population from serfdom into active participation in the social and economic life of the country. With this recognition of the Indian as a potential citizen there has come in Mexico a more general esteem for the old Indian civilizations, knowledge of which had been kept alive through the ages by the untiring efforts of a handful of priests and scholars, chiefly Mexican, but including some Americans and Europeans.

These men had interpreted and preserved the few first-hand native records that had survived the wholesale destructions of documents and religious paraphernalia. They had also collected and observed the material traces of native culture dug up by farmers and treasure hunters and had tried to identify the makers of these objects and the builders of these temples by interpretation of the native annals at their disposal. It became evident, as time went on, that there was vastly more material in the ground than could be accounted for by the tribes mentioned in the historical records.

Thus in the beginning of the twentieth century, a subsidiary branch of history began to grow up, field archeology, which had for its aim the study of the Indian material culture, its history and development, and its interpretation in terms of human history. One of the chief aims of this branch of research was to try to



TYPES OF STRATIGRAPHICAL EXCAVATION IN THE VALLEY OF MEXICO.
Top: *Left:* Deep Pit at El Arbolillo, Federal District, Mexico. The earliest discovered figurine types from the Valley of Mexico were discovered at the base of this trench. *Right:* Cleaning out a canal in the Nonoalco District of Mexico City. This shallow

establish the relative age of the different monuments and cultures. Fragmentary pottery was of the greatest aid in attaining this end. Forms and decoration changed gradually with the years, and each tribe or locality had its own individual expression. By cutting into ancient refuse heaps, where the material at the bottom was necessarily laid down at an earlier date than at the top, and by carefully studying the differences in shape, texture and decoration of the fragments of pottery found, it was possible to discern the relative age of several ceramic groups. Later, by finding pottery associated with a building, the relative age of that structure could be determined. Furthermore, in Central America, it is quite common to discover that buildings are successively enlarged by filling in and adding to a previous construction, so that the stratigraphical process can be applied to architecture as well as to ceramics.

While such stratigraphical sequences have been established for various parts of Mexico and Central America, the Valley of Mexico is the first where the archeological record is detailed enough to be compared to the historical and where the two lines of research complement and check each other. Let us examine this relationship, which is one of the primary ends of archeological research.

The documentary evidence from the Valley of Mexico consists of two main types. First there were the records kept by the Aztecs and their neighbors, a few of which escaped the wholesale destructions ordered by the Spaniards. These consisted of a type of picture writing, not unlike a rebus, in which the picture of an object could represent, beside the object itself, the same sound with another meaning or as a syllable in another word. Personages and tribes were represented in this way, while events were depicted pictorially. The dates of various incidents were also given in terms of a fifty-two-year cycle, but no method of distinguishing one cycle from another was evolved. This system caused the same kind of confusion as if we were to date our history in terms of a century only, so that an event recorded as falling in "65" might mean 1065, 1365 or 1865. The Aztec picture records were undoubtedly supplemented by chants or sagas, which gave detail and color to the simple annals set forth in the manuscripts, and some of the records have notes added at a later date in Spanish or Aztec which describe the native text.

Besides these indigenous documents, there were also histories written by Spanish priests and educated Indians after the Conquest. These authors seem to have had access both to the oral traditions and the pictorial records. In most cases their original sources have disappeared or else survive in copies distorted by European draughtsmanship. These later authors were often bewildered by the native method of dating, as would naturally be the case if one lacked a complete knowledge of the events of Aztec history. Thus, by confusing the various cycles, rulers are sometimes fantastically credited with 160-year reigns. But in the main the native records are fairly complete from 1200 to the Conquest and one or two accounts, written after 1519 but based on native traditions, reach as far back as the seventh century.

DITCH WAS FILLED WITH VESSELS DISCARDED IN THE CYCLICAL DESTRUCTION OF 1507. MIDDLE: EXCAVATION IN THE NONOALCO DISTRICT. NOTE THE EVIDENCE OF MODERN LIFE CONTRASTED WITH THE ARCHEOLOGICAL SITE. BOTTOM: *Left:* PEELING LAYERS OF REFUSE AT ZACATENCO, D. F. THIS WAS THE SOURCE OF THE FIRST STRATIGRAPHICAL SERIES DEFINED BY THE AMERICAN MUSEUM OF NATURAL HISTORY. *Right:* DISSECTING AN AZTEC RESIDENTIAL STRUCTURE AT CHICONAUHTLA, STATE OF MEXICO. THIS TYPE OF STRATIGRAPHY IS FAR MORE DIFFICULT THAN TRACING THE LAMINATIONS OF CULTURE IN A REFUSE HEAP.

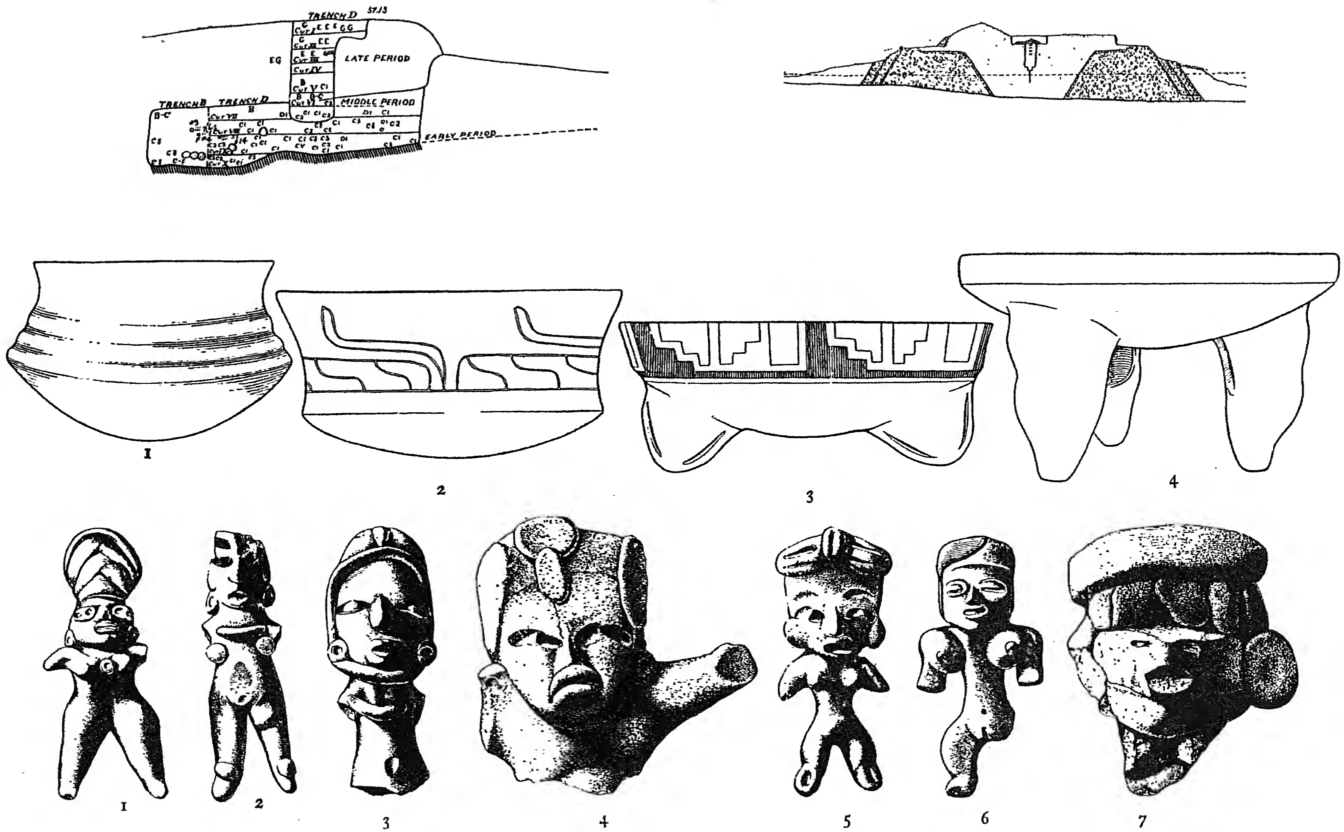


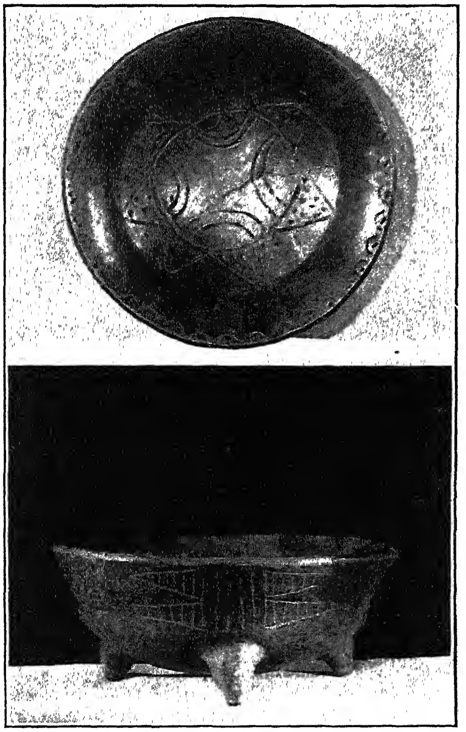
CHART SHOWING NATURE OF ARCHEOLOGICAL MATERIAL FROM THE ARCHAIC CULTURES.

TOP: NO. 1. SECTION THROUGH REFUSE HEAP; NO. 2. CROSS-SECTION OF MOUND AT CUICUILCO. MIDDLE: FIGS. 1–2. POTTERY VESSELS FROM THE COPILCO-ZACATENCO HORIZON. FIGS. 3–4. POTTERY VESSELS FROM THE CUICUILCO-TICOMAN HORIZON. BOTTOM: FIGS. 1–4. FIGURINES FROM SUCCESSIVE STAGES OF THE COPILCO-ZACATENCO CULTURE. FIGS. 5–6. FIGURINES FROM SUCCESSIVE PHASES OF THE CUICUILCO-TICOMAN CULTURE. FIG. 7. HEAD OF ARCHAIC TEOTIHUACAN TYPE, DERIVED STYLISTICALLY FROM FIG. 5.

The history recorded for the Valley of Mexico begins with mythological tales relating to the foundation of the world and to the presence on earth of gods and giants. Then follow accounts of the Toltecs, in which the supernatural is heavily involved. The lists of their rulers do not always agree, but there is strong evidence that the Toltecs actually existed, and the Toltec era is described as a golden age in Mexican history.

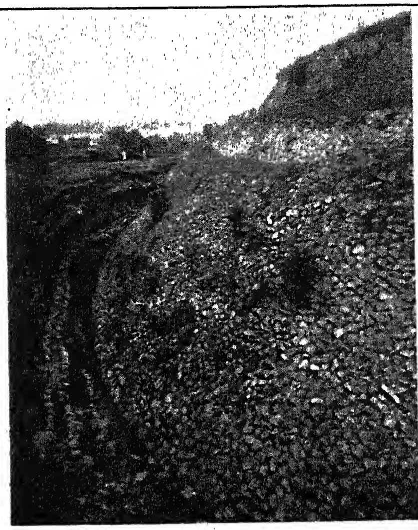
Famine and the incursions of savage tribes, the Chichimecs, brought an end to the Toltec Empire in the twelfth century. One of these entities settled in Azcapotzalco and through intermarriage with the remnant Toltecs picked up enough of the earlier culture to achieve a sedentary life. At the end of the thirteenth century Quinatzin, the fourth of the Chichimec line, moved his court from Tenayuca to Texcoco; but insurrection broke out in his former dominion and thenceforth there was bitter rivalry for the control of the Valley of Mexico between Azcapotzalco and Texcoco. In the second quarter of the fourteenth century two groups of people from the Mixteca came to Texcoco bringing not only writing, but also the cult of the god Tezcatlipoca. A few years later the Tenochca, or Aztecs of Tenochtitlan the modern Mexico City, along with several other groups, filtered into the Valley and became tributary to the Tepanecs of Azcapotzalco.

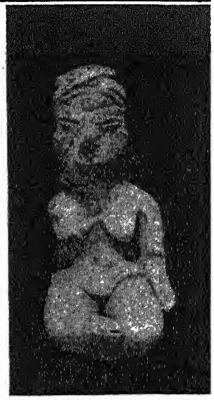
FIGURINES (TYPE C3a) FROM EARLIEST COPILCO-ZACATENCO CULTURE LAYER.

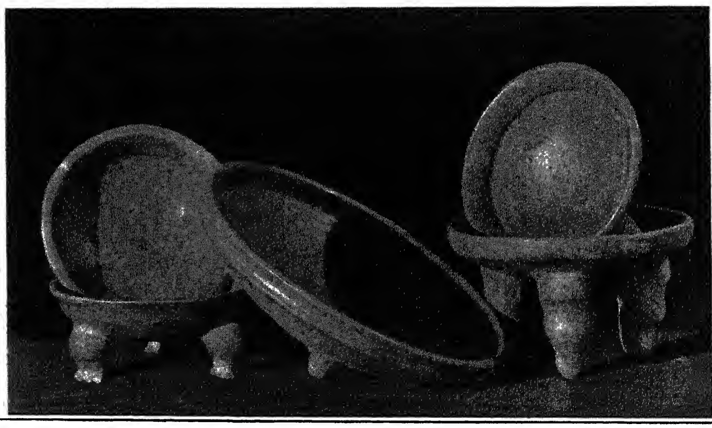


POTTERY VESSELS FROM EARLIEST COPILCO-ZACATENCO HORIZON.

At the close of the fourteenth century the Tepanec succeeded in overthrowing the Texcocans, but their sway was short-lived. In the second quarter of the fifteenth century, the deposed ruler of Texcoco raised a revolt, and enlisting the services of the Tenochcas or Mexico City







Aztecs and the Tacubans, destroyed forever the political power of Azcapotzalco. These three city-states then assumed the leadership of the Valley and by a series of conquests enlarged their power to cover great sections of southern and eastern Mexico. Gradually the Aztecs supplanted the Texcocans as the dominant political power in the league, but the cultural and intellectual leadership still remained with Texcoco. At the time of the Conquest the Aztec dominion was at its height, but the disaster in store for it at Spanish hands was but an acceleration of the seething hatred felt by the subject people who allied themselves speedily with the white invaders.

This history, culled from documentary sources, resolves itself into several stages or periods:

(1) The legendary period of the foundation of the world.
(2) The Toltec Empire.
(3) The Chichimec period.
(4) The formation of the Texcocan kingdom.
(5) The rise of the Aztec Empire.

We must now see how this pattern compares with the sequence of cultures, derived by excavation. This latter process has been a long one, lasting over twenty-five years, and still is not complete. While the Department of Monuments of Mexico and the American Museum of Natural History have been most active, yeoman service has been done by the now-disbanded International School, the Stockholm Museum and the University of Arizona. Now the point has been reached where a correlation can be made between the tribes of the Valley and their material culture.

Traces are found of five main culture levels, differing from each other in the form and decoration of their pottery, in the artistic styles of their stone and clay sculptures, and in their architecture. Through the study of the strata in the rubbish heaps, minor time stages can be distinguished within each culture group.

The earliest traces of man were originally found beneath a lava flow at the south of Mexico, but careful stratigraphical analysis of rubbish heaps in the Guadalupe hills, northeast of Mexico City, where similar material was found, revealed a long history for these finds, which resolved themselves into the handiwork of two peoples. The earlier culture, named Copilco-Zacatenco, after the sites where first found, showed five stages of development, represented in twenty-foot accumulations of refuse indicative of a long lapse of time. The general culture level was on a par with that of the more developed of our North American Indian tribes. The later finds, called Cuicuilco-Ticoman, could be divided into three time stages, derived from refuse heaps that, although deep, could not compare to the earlier deposits. In the Cuicuilco-Ticoman culture there were to be seen evidence of a considerable advance in handiwork, for not only were pottery, figurines and stone tools better made and in greater variety than in the preceding periods, but also the presence of mounds and unquestionable representations of gods indicated the beginnings of a formalized religious system. The wide geographic distribution of this culture shows that these remains were the handiwork of an important and populous tribal group.

The third horizon is marked by the finds made at the great pyramid city of San Juan Teotihuacan, northeast of

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SPECIMENS FROM THE ARCHAIC CULTURES.

TOP: *Left:* MOTHER AND CHILD FROM CUERNAVACA MORELOS. *Center:* PYRAMID OF CUICUILCO, D. F., NOTE THE LAVA ENCROACHING ON THE MOUND. *Right:* FIGURINE, CUERNAVACA, MORELOS. MIDDLE: *Left:* LARGE HOLLOW FIGURINE, CUERNAVACA, MORELOS. *Right:* HEAD, ZACATENCO, D. F. BOTTOM: POTTERY VESSELS OF THE CUICUILCO-TICOMAN CULTURE, TICOMAN, D. F.

Mexico City. While the earliest of the five periods tentatively defined shows affiliations with a branch of the Cuicuilco-Ticoman culture, the pottery and figurines present a rapid advance in technique and artistic value. Designs are often derived from ceremonial motives and testify that already that ritualistic preoccupation which so characterizes Central American civilization had taken form. Mighty pyramids and elaborate palaces give evidence of a closely knit social organization able to draft manpower to achieve such ends, while excellent stone sculptures indicate good craftsmen and trade with adjacent cultures. The last phase of this civilization is found at Azcapotzalco, apparently after Teotihuacan had been abandoned. Figurines were made in moulds, suggesting a curious use of mass production to satisfy the needs of mass religion, but architectural remains at Azcapotzalco reveal none of the grandiose qualities of Teotihuacan.

These first three culture groups have shown a slow development that reaches a peak in the civilization of Teotihuacan. The artistic forms and styles do not evolve progressively, but rather in jerks, as one tribe seems to have driven out another. The most violent change occurs with the introduction of the fourth culture period. Here, at San Francisco Mazapan, a simple complex of human handiwork is found overlying the Teotihuacan remains. While sporadic pieces, presumably obtained by trade, attest to the presence of relatively high civilizations elsewhere, the bulk of the material reveals little evidence of ritualistic, social or artistic advancement. By studying the traded vessels, connections are obtained with a series of other peoples, some of high and some of low culture, some inhabiting the Valley of Mexico and others as far away as Yucatan. It is as though with the collapse of the Teotihuacan civilization, a number of other tribes had risen to power and filtered into the countryside.

The last culture stage constitutes the articles of household and ceremonial use, the sculptures and the architecture found in places known to have been occupied by the Aztecs. One very characteristic ware may be divided into six periods, while other local forms and decorations reflect the presence of city-states mentioned in the chronicles.

The six Aztec pottery periods may also be grouped into larger units. The first period has been found in quantity at only one site in the Valley, Culhuacan, and stylistically these ceramics show affiliations with Cholula and the Mixteca, and, by trade pieces, with Mazapan. The second and third periods are closely united, and only minor differences in their coarse style of draughtsmanship distinguish them. The fourth and fifth periods produced highly conventionalized designs that are very similar, but many highly decorated polychrome wares attest to a wide trade. The last period styles evolve from the preceding but with a new element of naturalistic decoration.

Here then is the logical starting point for a correlation between the archeology of the Valley and its documentary history. If the six ceramic periods could be tied in with the annals of the Aztec, then there would be a fairly secure basis for testing the vaguer portions of the Valley's past. To this end a curious custom of the Aztec gave us a very good lead.

The Aztecs at the close of each of their 52-year cycles broke all their household utensils and put out their fires. Then they refurnished their houses and made new equipment. Presumably the temples and sacred buildings underwent a similar renovation. After midnight on the last day, a new fire was kindled on a hill outside of Mexico, and runners with torches distributed this flame to all the hearths in the Valley, while every one rejoiced that life was to continue for another 52-

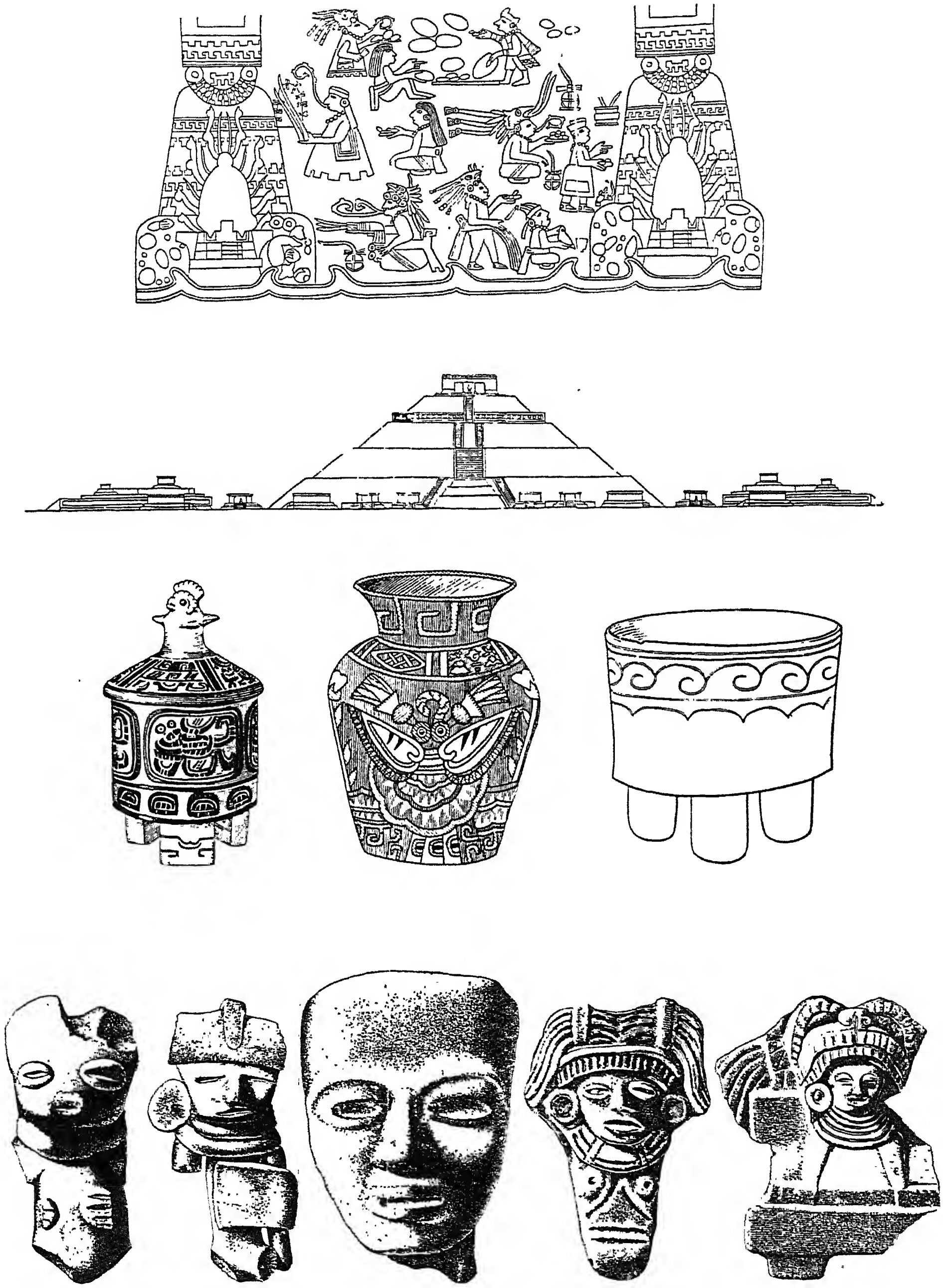


CHART SHOWING NATURE OF MATERIAL FROM THE TOLTEC CULTURE.

First Row: Fresco from Teotihuacan, showing people involved in a ritualistic ceremony.
Second Row: Reconstruction of the Pyramid of the Sun at Teotihuacan, after Gamio.
Third Row: Pottery vessels, Toltec Culture. The last is later than the first two.
Fourth Row: Successive stages of figurine manufacture in the Toltec Culture. The last two are mold-made.

year span. The native chroniclers record this practice punctiliously, for the Mexican calendar system was a sacred almanac for governing men's lives and served only secondarily as a means of recording time.

Reflections of this ceremony have been found in excavations around Mexico City, where broken pottery and idols were found in too great quantity to have been the result of accidents. Ancient temples, in which the successive additions give the nested effect of a Russian doll, also suggest a further application of this practice.

One of these cyclical dumps yielding pottery of the fifth Aztec style we uncovered last spring in the heart of Mexico City, at the power plant of Nonoalco. A normal refuse heap of the sixth and latest style lay above the ceremonial deposit. Since this latest type of Aztec pottery occasionally shows such traces of Spanish influence as glazed surfaces and European designs, it must have been in vogue at the time of the Spanish penetration of Mexico subsequent to 1519. Therefore we had good basis for assuming that the lower layer of the fifth period represented the destruction in connection with the last New Fire Ceremony before the Conquest, which was celebrated in 1507. Moreover, at Chiconauhtla, a frontier town of the Texcocan dominion, we found another ceremonial dump of this same fifth Aztec style under circumstances which proved it to have been made at the end of the occupation there.

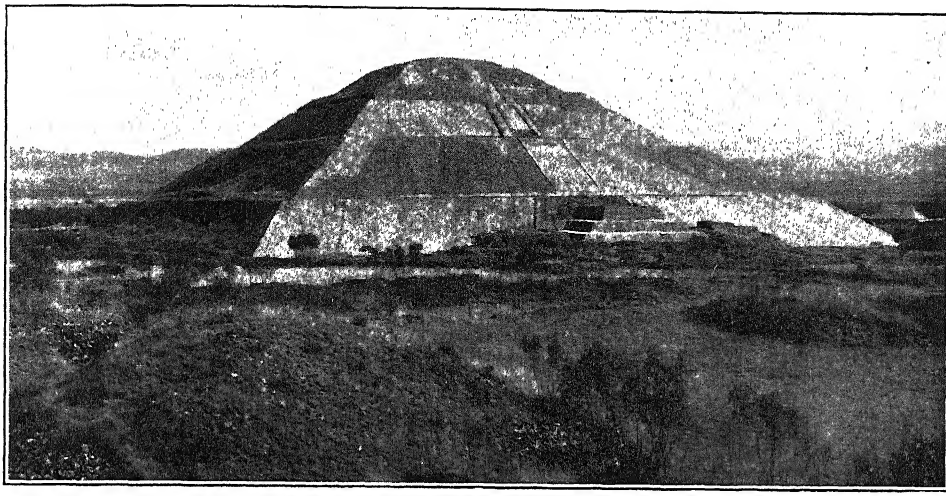
To strengthen our hypothesis we found two dumps of the fourth Aztec ceramic period, one at Chiconauhtla and another in Texcoco itself, an occurrence which would suggest the celebration of the New Fire Ceremony 52 years previous, or in the year 1455 (1507–52 = 1455). In one of the earlier buildings at Chiconauhtla, we came across another such dump composed of pottery of the third Aztec period, which, if our hypothesis was correct, would represent the cyclical destruction of 1403.

The second Aztec pottery stage was obtained from a low stratum of a normal refuse mound at Chiconauhtla, so that while we have no definite evidence that this earlier stage should span another 52-year period, we have some right to assume it was made between 1299 and 1351. Furthermore, the first Aztec period, as we have said, is found in quantity at only one site in the Valley, Culhuacan, and may well be contemporaneous with the Mazapan culture described above as representing the fourth epoch in the development of civilization in the Valley.

According to our reckoning, then, the Period 6 style, from 1507 to the Conquest, represents the last days of the Aztec Empire. Pottery of Period 5, which was made between 1455 and 1507, is widely distributed as befits the domination of the Aztec League. The method of decoration in vogue in Period 4, 1403–1455, is strongly represented at the palace of Nezualcoyotl, the great Texcocan ruler, and at Texcoco itself. At this time Texcoco rather than Tenochtitlan led in sumptuousness and splendor. The trade wares suggest tribute from the conquests of that era and the clay idols reproduce the wide variety of gods in the Mexican pantheon.

Pottery from Period 3, 1351 (?)–1403, is scantily represented at Tenochtitlan, which in this period was a weak tributary to Culhuacan and the Tepaneca of Azcapotzalco, but this style, like that of Period 2, 1299 (?)–1351 (?), is found in the other Valley centers. During the fourteenth century, as we have seen, the Tepanecs, Texcocans and Culhuas held the leadership of the Valley of Mexico, and the pottery attributable to this period is most commonly found in the towns under their dominion.

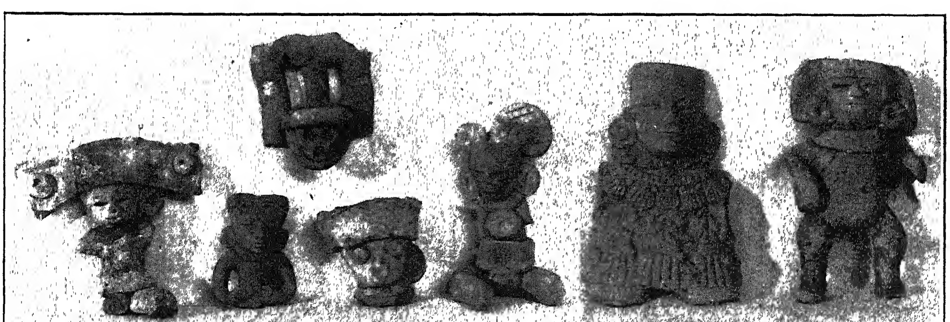
Confirmatory evidence of the reflection of time in ceremonial practice is



Photograph by Le Rochester
PYRAMID OF THE SUN AT TEOTIHUACAN, STATE OF MEXICO.

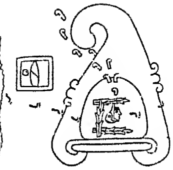
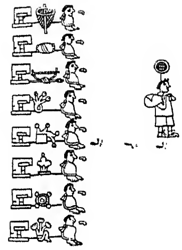
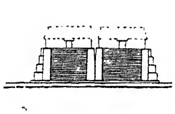
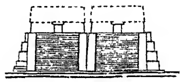
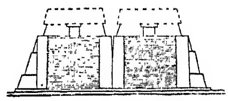
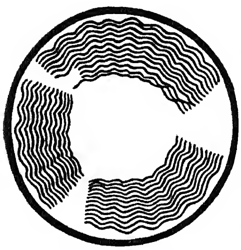
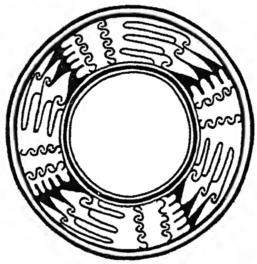
yielded by the pyramid of Tenayuca, where seven buildings are found superimposed. The last reconstruction presumably marks the ceremonies of 1507, the next two in the same style, those of 1455 and 1403. The architecture of the fourth (1351) is transitional to two more primitive pyramids possibly representing the ceremonies of 1299 and 1247 which corresponds very well to the early thirteenth century date given to the founding of the Chicimec kingdom in Azcapotzalco. The break from the primitive to the regulation Aztec style of architecture accords well with the historical data, which describe Quinatzin's becoming civilized and moving to Texcoco in 1298 and the arrival of Mixtecs and other tribes in 1328. A resemblance, too close to be entirely coincidence, exists between the tradition of the Mixtecs having brought knowledge of writing in 1328 and the Period 2 and 3 style of decoration which seems based more upon the fluid principle of writing than the previous labored method of painting designs in geometric fashion.

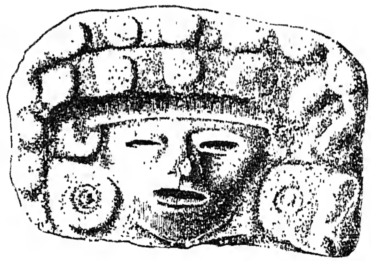
We have traced our way to the last half of the thirteenth century. Our records have become very hazy, and we now meet



TOLTEC FIGURINES. NOS. 1–5, TEOTIHUACAN II (EARLY TOLTEC) TYPE. NOS. 6–7, TEOTIHUACAN V (LATE TOLTEC) TYPE. NOTE IN NOS. 3–4 GROTESQUE FEATURES INDICATIVE OF SYMBOLISM DEFINING VARIOUS DEITIES.



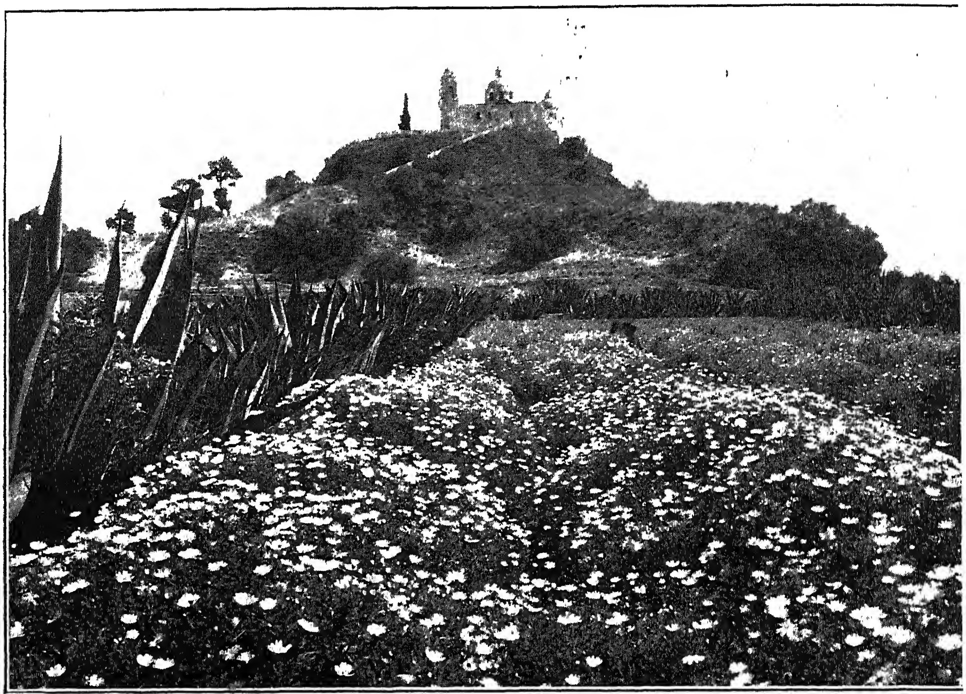


the Mazapan culture, the fourth level in the Valley. The chronicles tell of the incursions of the Chichimecs, who brought an end to the Teotihuacan culture some time in the twelfth century. We can rely no longer on ceremonial dumps, but we can achieve a relative dating in another way. Two trade wares are found in the Mazapan culture, Plumbate, a natural glazed pottery perhaps made in Salvador, and Fine Orange, which is common on the Isla de Sacrificios in Vera Cruz. Both these wares are frequently found in Chichen Itza in refuse of the Mexican period, which began about 1200 A.D., and lasted until 1458. That the Mazapan culture flowered in the thirteenth century seems extremely probable both because of its stratigraphical position below the Aztec-Texcocan material remains and above those of Teotihuacan, and because of the trade pottery which ties in with thirteenth century refuse heaps at Chichen Itza in Yucatan. The makers must then be some branch of the Chichimec immigrants, who, arriving in Mexico during this period, seem to have assumed distinctive tribal names even as, in adopting a sedentary life, they occupied fixed places of residence.

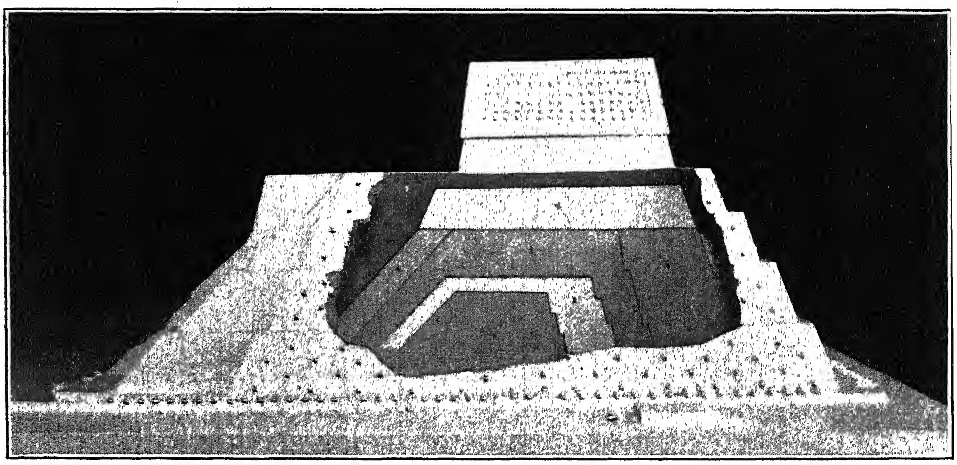
Following our method of elimination there seems no reasonable doubt that the Toltecs were the makers of the Teotihuacan civilization, a thesis which is supported by a great deal of legendary evidence. The long span of the 700–1200 A.D. dates assigned by some to the Tòltec Empire agrees well with the traditional evidence and the retarded cultural de-

LIFE-SIZE POTTERY EFFIGY FROM COATLINCHAN, STATE OF MEXICO. STYLISTICALLY THIS FIGURE SEEMS TO BELONG TO THE MAZAPAN CULTURE.

CHART SHOWING ARCHEOLOGICAL MATERIAL FROM THE CHICHIMEC CULTURES. TOP ROW: HISTORICAL PICTURE WRITINGS RELATING TO PERIOD. 1, CHICHIMEC HUNTER. 2, AZTECS SETTING FORTH ON THEIR WANDERINGS. 3, EIGHT TRIBES WHO SETTLED IN AND AROUND THE VALLEY OF MEXICO. SECOND ROW: SUCCESSIVE STAGES IN THE CONSTRUCTION OF THE TEMPLE OF TENAYUCA WHICH EPITOMIZES THE ARCHITECTURE OF THE CHICHIMEC AND AZTEC PERIODS. THIRD ROW: POTTERY STYLES OF MAZAPAN, COYOTLATELCO AND AZTEC I TYPE WHICH MAY EVENTUALLY BE CORRELATED WITH SOME OF THE TRIBES SHOWN IN TOP ROW (3). FOURTH ROW: FIGURINES OF COYOTLATELCO TYPE. FIFTH ROW: FIGURINES OF MAZAPAN TYPE.



TEMPLE OF CHOLULA, PUEBLA.
BENEATH THIS LARGE ADOBE PLATFORM IS A COMPLEX OF BUILDINGS OF THE TOLTEC PERIOD.



MODEL OF THE TEMPLE AT TENAYUCA, D. F.
SHOWING SUCCESSIVE RENOVATIONS MADE IN CONNECTION WITH THE RENOVATION CEREMONIES AT THE BEGINNING OF CALENDAR CYCLES. THE SIX BUILDINGS SHOWN MIGHT CORRESPOND TO STRUCTURES MADE IN 1507, 1455, 1403, 1351, 1299, 1247.

velopment one would expect of people who could not borrow but had to invent each material and cultural innovation. Furthermore, this hypothetical dating is roughly substantiated by the discovery of the Swedish archeologist, Linné, who found, in a Toltec building on the outskirts of Teotihuacan, Peten Maya trade pottery like that associated with the dated Maya monuments (*circa* 433–889).

While the historical position of the Valley of Mexico Toltecs seems to be fairly well established by the correlation of archeological and historical data, there is still confusion attendant to the cultural identification of people called by the same name in other districts of Mexico. Further research should clear up the identity of these tribes, as either colonists driven out of the Valley or outlying branches of the same group who retained their tribal organization although modifying their culture, or perhaps people completely different culturally and tribally who were given this name as a generic distinction, even as the discoverers of America called its inhabitants Indians.

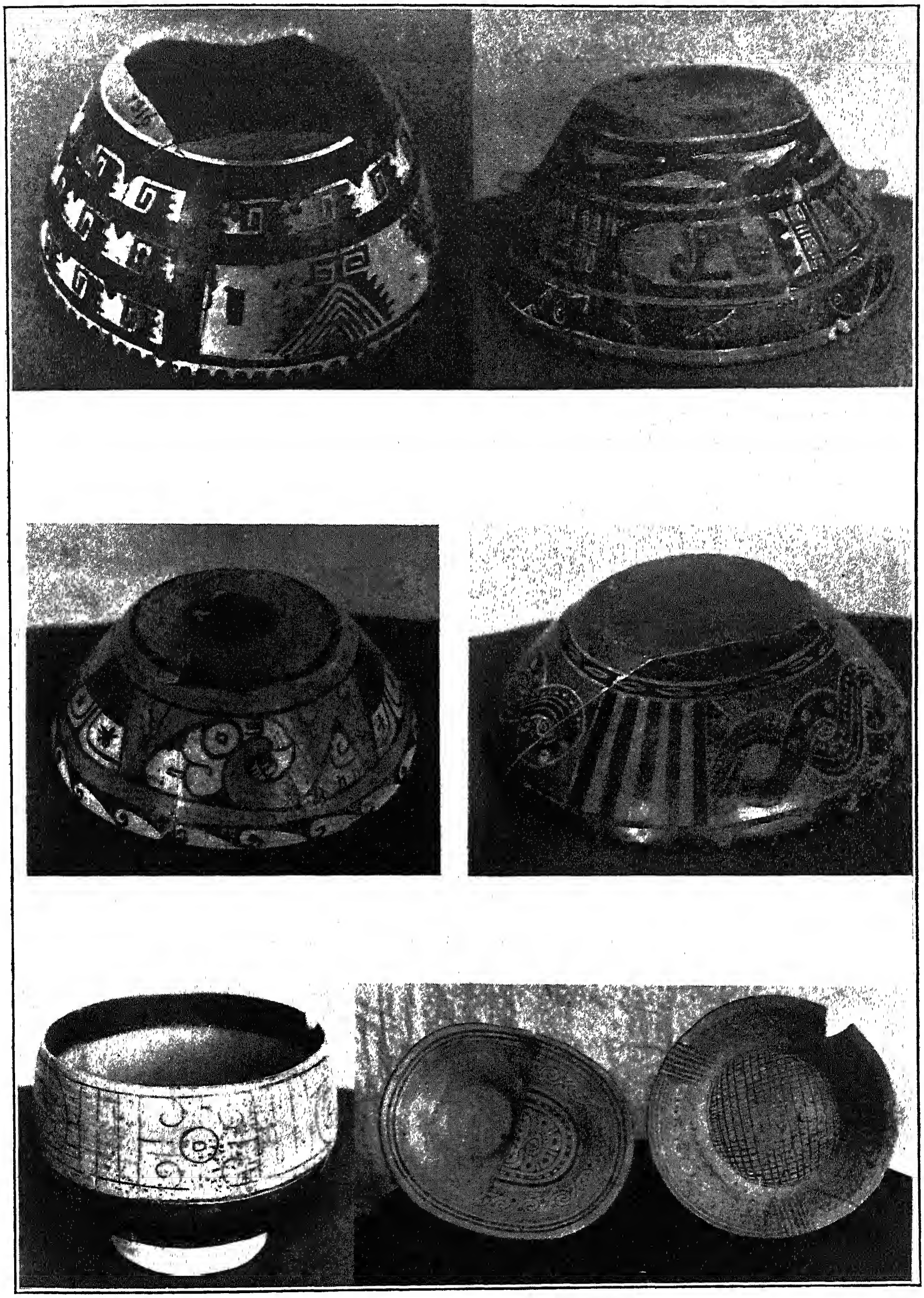
With this final identification, connection between traditions and archeology ceases, so that we can not identify the makers of the Cuicuilco-Ticoman and Copilco-Zacatenco cultures, often grouped under the term "Archaic." True, the mythology records giants as inhabiting the earth before the advent of the Toltecs, but the skeletons found in graves of these periods give no evidence of extraordinary size. It would be tempting to align with mythical destructions of the world the rise in lake level which affected the Zacatenco culture or the lava flow from the Pedregal which surrounded the ruins of the Cuicuilco pyramid. As these successive destructions were by Jaguars, Wind, Fire and Water, the order is wrong for such an interpretation of the geological disturbances affecting the Early Cultures, but it is possible that a vague folk memory of such events may have been incorporated in the myths.

The dating of these Early Cultures is impossible in an absolute sense, but, relatively, some estimate may be made. The geologists all agree that the lava flow is recent, but their computations of 2,000 to 8,000 years are meant to be taken in

UPPER: POTTERY EFFIGY VASE FROM MAZAPAN STATE OF MEXICO. LOWER: TWO BOWLS OF PLUMBATE WARE FROM MAZAPAN. THIS IS AN IMPORTANT WARE FOR CROSS DATING CULTURE PERIODS.

the geological sense of extreme youth instead of the historical sense of great age. There is some evidence that the Ticoman-Cuicuilco culture is partially contemporaneous with Teotihuacan. It is also possible to compare the accumulations of rubbish at Zacatenco and Ticoman with those of a site in New Mexico, Pecos, the

CHART SHOWING ARCHEOLOGICAL MATERIAL FROM THE AZTEC CULTURE. FIRST ROW: SCENES FROM HISTORICAL PICTURE MANUSCRIPTS. (1) ARRIVAL OF NATIONS WITH THE KNOWLEDGE OF WRITING IN 1325; (2) NEW FIRE CEREMONY OF 1403; (3) NEW FIRE CEREMONY OF 1455; (4) NEW FIRE CEREMONY OF 1507; (5) THE TAKING OF TENOCHTITLAN (MEXICO CITY) IN 1519. SECOND ROW: SUCCESSIVE STAGE IN THE ARCHITECTURE OF THE TEMPLE AT TENAYUCA CORRESPONDING PERHAPS TO THE RENOVATIONS OF 1403, 1455, AND 1507. THIRD ROW: (1–3) AZTEC POTTERY TYPES (II, IIIa, IIIb) FOUND IN THE CYCLICAL DUMPS FOR 1403, 1455, AND 1507. (4) POTTERY TYPE (IV) MADE FROM 1507 UP TO THE CONQUEST. FOURTH ROW: (1–2) AZTEC FIGURINES MADE PRIOR TO 1403. (3–6) AZTEC FIGURINES MADE BETWEEN 1403 AND THE CONQUEST.



AZTEC POTTERY TYPES.

TOP: TRICHROME VESSELS FOUND IN A 1403 CYCLICAL DUMP AT CHICONAUHTLA. MIDDLE: *Right:* TRADE BOWL FOUND IN 1507 DUMP AT CHICONAUHTLA. *Left:* LOCAL TRICHROME BOWL FOUND IN THE 1507 DUMP AT CHICONAUHTLA. BOTTOM: *Left:* ORANGE ON RED BOWL WITH BLACK OUTLINE FROM NONOALCO. *Right:* BLACK ON ORANGE DISHES FROM NONOALCO.

occupation of which is accurately known in years by means of the tree ring method. Dividing the number of years by the greatest depth of continuously deposited debris at Pecos, one gets a ratio of 78 years to the meter. Applying this computation to the deepest refuse heap at Ticoman, one finds 286 years of accumulation, and to the thickest middens of the Copilco-Zacatenco culture, 787 years. Perhaps a thousand years is excessive, so that computing on the basis of the deepest bed which shows continuous occupation by both cultures, one arrives at nearly 600 years for the total length of habitation.

Rough and inaccurate as these computations are they indicate that the Valley of Mexico was inhabited for a long time before even the dimmest historical records, and that the earliest remains so far recovered were made in the first centuries before the Christian Era. However, these early people were by no means primitive. Indeed they were on a par already with our modern Pueblo, and there are many stages of culture to be discovered and analyzed before we can say we have traces of the earliest man in Central America.

This article has endeavored to sketch one phase of historical research on the past of Mexico. A major problem has been to bridge the gap between the peoples who are identified by Spanish and Indian documentary records and those who are known to us only through the ruins of their buildings and the broken elements of their material culture which have survived. While at times it must seem as though the archeologists labor to make bricks without straw, yet the results of the Valley of Mexico research prove that it is possible to formulate a history with the meager data provided. In Yucatan, Guatemala and Oaxaca, similar methods have sketched the main outlines of historical development. Even if the history thus obtained discloses little or nothing of the life of the individual, it does throw abundant light on the steps by which man achieves his artistic development and economic progress. The lesson is constantly driven home that greater than man is the sum total of his achievements.

SOME NEGLECTED ASPECTS OF PLAGUE MEDICINE IN SIXTEENTH CENTURY ENGLAND

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For the historian few subjects fail to profit from a reexamination and a restatement of pertinent data, and plague medicine proves no exception to this generalization. While historical revisions often bear some characteristics of a lark —a rather pedantic lark, to be sure— they generally convey more than an antiquarian interest and express more than a mere erudite whim. Generations of historians and shoals of other writers have, whether intentionally or ignorantly, fastened upon the political and medical authorities of the sixteenth and seventeenth centuries a genius for ineptitude, stupidity and even deliberate cruelty. A statement made recently by a competent historian in connection with the plague of 1665 that "beyond insisting on isolation and prohibiting the holding of the great fairs, the government did little," is one of the gentlest criticisms of public policy. Much oftener writers scornfully denounce the "optimistic credulity" of these earlier days in contrast to the "sceptical science" of our own, and they even deplore the omission of policies which many governments to-day would hesitate to put into effect in their entirety. Such critical and scornful hindsight illustrates only too well the practice of reading history backward.

Considerable and varied evidence, however, indicates that this view-point does not comprehend the whole story. During the sixteenth century the magistracy, both local and central, often tried to combat the plague by methods that might well gain the applause of a modern health officer. In order to appreciate that fact the gleanings of numberless records are necessary; but from these come the realization that preventive medicine was not born yesterday. Too long have the quaint recipes and prescriptions, interesting and significant though they may be, been allowed to describe the quality of sixteenth century medicine, and for that matter the character of pre-nineteenth century science as well. Yet these no more provide an adequate account than the assumption that patent drugs or folklore remedies comprise all of modern medicine. The bumptiousness of much recent popular science has encouraged many people to assume that before some vaguely generalized epoch like the world war all was darkness and barbarism. Popular writers, and others who ought to know better, forget that modern medicine, which of itself may or may not be so very *scientific*, stands on the shoulders of earlier medicine which may or may not have been so very unscientific. As it takes more than a few test-tubes to make a modern doctor, it took more, or perhaps less, than their absence to make a sixteenth or seventeenth century quack.

Bizarre methods of combating the plague prevailed of course in all sections of the country and in all strata of society, but alongside these seemingly ridiculous antidotes stood the careful, intelligent observations of men who had a fair claim to be considered the harbingers of a more scientific medicine. Medicine based on acute observation and exact experiment was by no means the exclusive product of the nineteenth century, nor has it entirely superseded prac-

tices which snobbery pleases to designate as medieval. Whatever the approach to the medical ideas and practices of an earlier day, comparisons must be made between similar groups. Writers should compare old wives' tales and modern quackery, not old wives' tales and the Mayo clinic. If they wish to emphasize medical progress, they should not compare Banting with some nameless apothecary who with all his nostrums menaced his customers no more than the manufacturers and vendors of Ex-lax or Father John's Medicine injure theirs, and probably did it less expensively. So, as the thousands of yesterday were oftenest prone to depend on recipes which they knew best and could get the easiest, the millions of to-day attempt to secure pep or good temper or healthy nerves or a trim figure by a treatment no more rigorously clinical than that used by their ancestors.

Moreover, in respect to what appears a credulous way of defeating the plague by laying the belly of a live frog or the rump of a live cock chick to a plague sore it may be mentioned that all contemporaries did not take such methods over-seriously. For example in 1561 there appeared the following parody on such nostrums (spelling modernized):

> Take a pound of good hard penance, and wash it well with the water of your eyes, and let it lie a good while at your heart. Take also of the best fine faith, hope and charity that you can get, a like quantity of all mixed together, your soul even full, and use this confection every day in your life, while the plagues of God reigneth. Then, take both your hands full of good works commanded by God, and keep them close in a clean conscience from the dust of vain glory, and ever as you are able and see necessity to use them. This medicine was found written in an old bible book and it hath been practised and proved true of many, both men and women.

As Macaulay's omniscient school-boy would know, the plague had been visiting England for centuries before the last great epidemic in 1665. During the seventh century—to go no farther back—it raged extensively for twenty-five years after the Synod of Whitby (664), driving large numbers of people back to paganism and at the same time disorganizing society and politics. In the millennium that followed the plague made innumerable visitations, of which the most famous was that of 1349, although many others had consequences scarcely less disastrous for limited areas. Full testimony has survived concerning the effects of the most extensive of these epidemics, and in the case of the Black Death writers have not hesitated to attribute every sort of disaster to its destructive blight. Later plagues have not been credited with such revolutionary consequences, possibly because they came with such frequency that familiarity may well have consummated its proverbial destiny and have bred contempt in the minds of contemporaries. Yet contemporary indifference should not be taken as evidence of no influence, for in any case the efforts at control indicate realization of potential disaster.

As early as 1518 the government drew up and enforced orders for the prevention of plague in London. The city magistrates bore the brunt of the responsibility, but the constable actually carried out the orders by reporting to the mayor the number who died, by closing and marking the houses of the infected and by arresting the beggars and idlers. In addition, special officials called "examiners" were appointed to keep an eye on the state of the plague. The authorities did not stop with this, however; they ordered that no clothes or bedding about any infected person should be sold or given away. They likewise enforced segregation, a policy more or less in force since the Black Death. Feasts and assemblies were postponed, infected persons were forbidden to attend church, theaters were closed, houses visited by the infection were marked with a red

cross and an inscription, "Lord have mercy on us," for forty days, and no inhabitant of these houses was allowed to leave the house without carrying a white rod four feet long. These rules or variations upon them applied during subsequent visitations, but the authorities did not rest content with them, for new measures were constantly introduced. In 1535, for example, no one was allowed to bring oysters into London, on pain of imprisonment; and during the next few years, in order to prevent the spread of the infection, royal proclamations frequently denied people access to the court and adjourned the law courts.

By the middle of the century other restrictive policies were in practice. In 1547 the Privy Council required all persons in whose houses the plague had visited to put a cross on their street door. Burial regulations became steadily more strict. The government prohibited crowds from gathering at funerals and commanded the curates and others that no corpse should be buried before six in the morning or after six at night and that there should be at least one bell rung at the burial of every corpse. The authorities likewise investigated improper methods of burial, but here they did not accomplish much, because burials were bound to be hasty on account of inadequate facilities and inasmuch as parish churchyards could not possibly contain all the plague-stricken dead. Moreover, corpse bearers employed at a stipulated wage were required to carry red wands when they passed along the streets.

The terrible inroads made by the plague during the early years of Elizabeth's reign compelled constant and exhaustive efforts at relief. In August, 1563, the council warned lest returning soldiers spread the infection, and in the following March ordered the officers of Westminster to shut up all houses visited by the plague and see to it that the inmates did not venture out. At the same time magistrates collected money for the quarantined poor and sought to prevent crowding.

Shortly afterward the Mayor of London commanded every one to draw ten buckets of water before six in the morning and pour them in the streets and gutters. The streets were to be swept every day before six in the morning and after six in the evening when the gutters were to be cleaned. Scavengers were to remove the filth from the street every second day at least. Because of the conviction that dogs carried the plague from house to house he appointed special officers to kill and bury dogs found loose between 10 P. M. and 4 A. M. Cats, rats, swine and pigeons were also thought to be very dangerous, and steady efforts curtailed their carrying activity. Likewise, the mayor commanded every man in every street and lane to make fires three times in the week and appointed two poor men to burn such straw, clothing and bedding as they should find in and near the city whereon any plague-stricken person had laid or died. He ordered an inquiry into the number of persons who had died of the plague in the various parishes; he required the church wardens to give notices of plague-infected houses, to forbid every person therein coming to church for one month following the visitation, and to fix a blue cross upon the door; and he commanded the plague-stricken persons to remain constantly in the house, with doors and windows shut, for forty days. Finally, orders gave directions for preventing infection and fumigating the houses as well as describing symptoms and suggesting remedies.

Although these measures only affected London, preventive measures were by no means limited to the capital. At Liverpool, where narrow, ill-kept streets and defective sewerage no doubt had much

to do with the prevalence of the scourge, several orders went into effect. In 1558 the magistrates ordered that all persons struck by the plague should leave their houses and set up their abode outside the city on the heath. Those who did not leave were "to keep on the back side of their houses, and keep their doors and windows shut on the street side until such time as they have licence from the mayor to open them," and no other persons were to dwell with them. In 1562 it was found "very expedient that all dunghills and middings be clearly and clean taken away." Winchester and several other towns halted their fairs. At Maidstone the authorities addressed themselves to the difficult and common problem of caring for the sick. Often the healthy ran off, leaving the victim, who perhaps in the end might die of starvation rather than of the plague itself. Therefore, the mayor or his deputy could appoint persons dwelling in the town almhouses "to do ther true endevour, dylygence and servyce for the comforte, helpp and succour of the syck." In case of refusal such persons could be turned out of the almshouse. In 1565 the privy council, considering that the two universities were "instituted for the education of youth, and maintenance of such as teach the liberal sciences, . . . good means should be used to preserve them in peace, and to keep them free" from infection. Therefore Cambridge University was charged to have good regard that no open shows be made and to suffer no assemblies of vulgar people who might bring the infection, within that university or five miles compass.

Such provisions, however, ought not to be taken as the full measure of antidotal legislation, and it would be less than historical to neglect, in passing, the fact that the help of God was not scorned. In 1551 the king desired the bishops to exhort the people to a diligent attendance at Common Prayer and so avert the displeasure of God who had visited the realm with the "extreme plague of sudden death." Then there was also the special prayer in the Book of Common Prayer: "In the tyme of any common plague or sickness O Almighty God . . . have pitie upon us miserable synners, that nowe are visited with great sickness and mortalitie. . . . So it maye now please thee to withdrawe from us thys plague and grevous sickenesse, throughe Jesu Chryste oure Lorde." In 1564 the council proclaimed a thanksgiving for release from the plague.

Probably an even better example of this attitude of mind was to be found in the letter of Queen Elizabeth to Archbishop Parker in 1562.

> Considering the state of this present time, wherein it hath pleased the most highest, for the amendment of us and our people to visit certain places of our realm with more contagious sickness, than lately hath been; for remedy and mitigation whereof, we think it both necessary and our bounden duty, that universal prayer and fasting be more effectually used in this our realm. And understanding that you have thought and considered upon some good orders to be prescribed therein, for the which ye require the application of our authority, for the better observation thereof amongst our people; we do not only command and allow your zeal therein, but do also command our manner our ministers ecclesiastical or civil, and all other our subjects to execute, follow, and obey such godly and wholesome orders, as you being primate of all England, and metropolitan of this province of Canterbury, upon godly advice and consideration, shall uniformly devise, prescribe, and publish for the universal usage of prayer, fasting, and other good deeds during the time of this visitation by sickness and other troubles.

Admitting, however, that prayer and fasting were frequent methods of combating the plague, it must be remembered that they generally were substantiated by concrete preventive action. In October, 1568, the authorities restricted the visits of outsiders to London and during the following year limited the movement of people about the country, even going so far as to halt all traffic between Lon-

don and Windsor. In fact, a good many men and women, chiefly vagabonds, were whipped for not obeying these restrictions and who were therefore regarded as spreading the plague. Moreover, fairs were prohibited, courts adjourned and the sale of fruit forbidden on the London streets. Both the Privy Council and the town governments never ceased to consider how the spread of the plague might be halted. Officials constantly inquired as to how the various orders were being enforced throughout the country and as to the number of deaths. Even in Scotland, where it might be supposed that preventive measures would not be so carefully practiced, the same process went on. In July and September, 1564, for example, ships from Dantzig, where the plague flourished, were put in quarantine and their cargoes fumigated.

In 1574, a curious proclamation from the London mayor and aldermen, with the express purpose of avoiding the spread of the infection within the city, ordered all persons living in houses where the plague had visited within the preceding month or which should hereafter be affected not to come abroad into "any streate, market, shoppe, or open place of resort" within the city or its suburbs, until the plague had ceased in the said house "by the space of xx dayes at the least" except they carry in their hands openly one white rod at least two feet in length, upon pain of losing forty shillings. Also the clerk or sexton of every parish was commanded to set upon the door of every infected house a paper with the words, "Lord have mercy upon us," and to see to it that the same be not pulled down until the plague had ceased in the marked house by the space of one month. Finally no person having the plague should come abroad until the plague sore was fully healed.

In July, 1575, when the plague broke out at Bristol, ordinances required the taking of measures to avoid the plague, but they proved unavailing. Moreover, in the same year, when the government heard that the justices had left the town of Stamford to get along as best it might without making any provision for the poor, it deplored such a practice as not only bad for the town but also as likely to spread the infection abroad in the counties round about. In the following year the authorities of Kingston-upon-Hull complained that as the quarantine was not being strictly performed seamen brought the plague into the town. Because the infection chiefly affected one particular end of the town, special precautions were enforced there, porters handing in the provisions and standing guard day and night to prevent the sick from going out. At Northwick in Cheshire the linen of a plague-stricken household was thrown into the river to prevent its further use.

In London in 1578 the corporation appointed two "honest and discreet matrons" in each parish to search out and inspect every corpse in order to discover what had caused the death. The fact that these "matrons" often proved dishonest and indiscreet should not disparage the intent of the magistrates to halt the infection. Two nurses were also appointed for each parish to wait on the inhabitants of infected houses and to take care of the sick.

London, however, did no more than other important population centers. When Norwich was seriously menaced in 1579 some comprehensive orders appeared, inspired largely by the failure of some newcomers to keep their houses clean, by their practice of infecting the river with their washing, and also by "pouring out wash in their gutters, and not pouring water after it, whereby it resteth in the gutters and breedeth great infections." To reform such practices "a law was made, and a precept directed to them to redress the same." These people were commanded to take good regard

that their "necessaries be kept dry without washing, for the wash corrupteth and bringeth great infection, and use such cleansing of your houses, your clothes and bodies, and also such fumes and preservatives as the physicians shall advise you." They were told to kill all dogs within infected houses and suffer none at all to "wander and stray from house to house, but to be kept tied at home at their several houses," upon pain of imprisonment and fine.

At Yarmouth in the same year, liberty was given the fishermen to sell their products elsewhere at their pleasure, and tents and booths were erected outside the town so that they did not need to come inside "to make price of their herrings." Likewise the magistracy of Newcastle wrote the bailiffs of Yarmouth forbidding, on account of the grievous plague there, ships to come to Newcastle as usual for coals. At Ipswich in order the better to avoid the plague an ordinance provided "for supplying meat, drink and extraordinary diet to infected and necessitous persons" and required also "that every house so happening to be infected to have a load of weed" burned in it for airing purposes. At Canterbury a poor priest was employed during the thickest of the pestilence to kill the cats and dogs in the street, for which he received a set sum paid by the city.

Meanwhile, at London the plague continued and with it additional preventive measures. In 1580 the Privy Council forbade the bringing of goods from Paris, where there was infection; and five years later, the plague being at Bordeaux, the council prohibited commercial intercourse with that city for eight months. In 1582, when it appeared that the plague would again visit London, many precautions both old and new were enforced. People suffering from the plague themselves or having had it in their houses were, when they went out, to carry a white rod, one yard long, and persons from plague-stricken areas were ordered not to visit London. Furthermore, the Lord Mayor placed restrictions on burials, which so frequently were made in shallow graves and too close together.

At the same time the council informed the mayor that the Queen had ordered the courts to meet at Hertford and that he should "publicly prohibit any merchant, victualler, retailer, or other person within the city, whose houses either had been or then were touched with the infection," from sending into Hertford or places near it "any kind of merchandise, stuff, bedding, victual, or such like, upon pain of imprisonment:" In reply the mayor informed the council that "he had caused inquiries to be made of all victualling houses, which had been infected. A catalogue had been made with names of the dwellers, a description of the places, which had been prepared for printing, and set up as proclamations."

Likewise because of the prevalence of the plague in London, in 1582, the Oxford magistrates requested the mayor "to restrain all such your citizens from coming to the . . . fair, of whose houses and families there is any manifest token of that infection." In the following year, the Winchester corporation ruled "that if any house within this city shall happen to be infected with the plague," every person should keep his dog in the house. If any dog should be found at large, the beadle or any other person could kill it, and the owner should lose 6s. At Durham in 1589 the poorer people were removed into huts on the adjacent common in the hope of checking the infection, and at Plymouth in 1590 some "stufe was burned for avoiding the sickness." When at this time the Yarmouth authorities feared the possible return of the plague, women were appointed to visit the houses where any sickness or death should happen and report whether

or not the plague had been the cause and if such should prove to have been the case these houses, where the parties could not supply themselves, were to be supplied with all necessary things by a general collection. Every Saturday night lists were to be made of all who had died the previous week and of all infected houses. And it was further ordered that no one should resort to an ale-house except with a stranger and for especial business, and that all bedding and clothes coming out of infected houses should be carried outside the town to be aired, on pain of being burned.

When the heavy visitation of 1592–94 occurred, authorities everywhere took the most extraordinary precautions, for of all the epidemics in the reign of Elizabeth none was so grave in mortality or so far-reaching in its effects. The London council on September 7, 1592, ordered those having wells or pumps to pour, every morning before six o'clock and every evening after eight o'clock, at least ten buckets of water down the gutters, required the filth of the streets to be raked up, and commanded the constable of the precinct daily to make sure that the words, "Lord have mercy on us," remained on the door of an infected house for twenty-eight days, and if the same were defaced or taken away with the consent of the inhabitants of the house he should post a new paper and continue the segregation of the inhabitants for twenty-eight days from such defacing or taking away. Pavements were to be kept constantly in good repair to prevent the standing of water or accumulation of filth which might aid infection. Any one going on the streets with a sore running was to be imprisoned for twenty-eight days. An agreement was made with the College of Physicians that a certain and adequate number of physicians and surgeons be appointed and notified to attend the sick and that none but these deal with the infected. Warders were also appointed to watch outside the houses of infected people who did not observe the regulations and to arrest persons coming out of houses contrary to orders. Persons having had contact with the infection, either directly or indirectly, were to carry a red rod one yard long.

At about the same time the Privy Council issued a number of orders affecting other parts of the country. The soldiers levied in northern England were marched around London on their way to Southampton, in some cases levies being stopped altogether, and merchants were forbidden to resort to Portsmouth. Some prisons were even cleared of debtors. The council also ordered the mayor and sheriff of Dartmouth to forbid any one to visit London to buy goods during the plague and to put in prison those who disobeyed. Sir John Hawkins, the head of the Admiralty, took especial measures at the navy yards, and ended the making of starch at Deptford "because of the number of dogs used therein, which being a noisome kind of cattle, especially at this contagious time," were very apt to bring the infection.

The council then complained because the London magistrates refused to allow fires in the streets, since these, along with exploding gunpowder, had been found effective in purging the air, and they declared that if diligence were not used the Queen would suspend the sitting of the law courts. That the Queen's household might be better preserved, the council commanded that no one, except those who had good cause, repair to her court or within two miles of it. Nor should any one attending on the Queen repair to London or to places within two miles of the city without a special license in writing, upon pain of imprisonment by the Knight Marshal, who was to search for all vagabonds that haunted the court.

Early in 1593 when the plague returns, which for some time had been

diminishing, began to increase the council rebuked the mayor and aldermen for their negligence, either because they did not observe good orders for preventing the plague or because their orders themselves were insufficient. The magistrates therefore were commanded to take immediate notice of all houses infected or suspected of infection and to shut them up either by locks hanging outwardly on the doors or by a special watch on every house. The infected were to be prevented from mixing with the well and were to be taken care of while in isolation. The mayor and aldermen were further warned that if they continued to be careless, the Queen, in addition to the punishment she already meant to inflict on them, would remove Parliament from the city. Because of the increase of the plague the council prohibited all manner of concourse and public meetings, preaching and divine service excepted, at plays, bear-baiting, bowling and other assemblies, with the result that regular theater-playing ceased until June, 1594.

A little later the mayor was bidden to take extraordinary care to prevent the increase of the infection, and to keep the streets clean and sweet. All infected houses were to be shut up and watched, and the other orders already devised were to be obeyed. The justices of Middlesex likewise were charged to allow no dung or filth to breed infection. Meanwhile the council, keeping close watch over the general course of the plague, had to consider the great difficulty which the more remote parts of the country experienced in obtaining supplies for remedies. Consequently, it instructed shire towns to stock such supplies and appended a list of preventives and cures to its orders.

In May, 1593, the master of the Savoy Hospital was to forbear to receive any into the hospital because of the danger that the poor people repairing there daily may be infected with the plague, to the great danger of the inhabitants in general and especially to some of the council that dwell in those parts and are often occasioned to be at court and near the Queen. In the same month the Trinity term of the law courts was adjourned, owing to the increase of the plague. The following month, because the Queen intended to remain at Windsor for most of the summer, the Mayor of Windsor was to prevent people coming from any place where there was any infection from entering the town. Those persons who obstinately and undutifully refused to obey orders should first be admonished to move their families and then, if that failed, they were to be brought before the council to answer for their contempt.

At the end of June, the customary great feasts made by the City Companies were curtailed and the money saved was to be converted to the relief of the infected. Because of continued negligence in the matter of allowing infected houses and shops to remain open or of compelling them to be shut only a short time, the mayor and aldermen were warned that, unless reform took place, the Queen would be moved to commit the government of the city to others. A few days later the mayor requested that, because of the great discommodity that would attend the prohibition of St. Bartholomew's Fair, the proclamation of the council forbidding that fair might be stayed until it were seen whether "by God's goodness and the Lord Mayor's careful endeavor the increase of sickness be allayed." At the same time he suggested that since the white crosses painted on those houses visited by the plague were easily wiped away, red crosses be nailed on the doors and a watch kept to prevent those within from going abroad. Because "God's goodness" and the mayor's "careful endeavor" did not prove sufficiently effective, the fairs usually held in the months of July, August and September were abandoned, the Queen pre-

ferring the preservation of her subjects to private benefit.

Due also to this increase in the plague the council informed the mayor and the aldermen that although the plague proceeded from God as a due punishment of wickedness all possible means ought to be used to prevent the spread of the infection. If, it was said, as good care were used in keeping the orders as in making them, especially in restraining the infected from the sound, it would with God's help do great good. It was recalled that at Kingston, upon the first infection, they caused a house to be made in the fields distant from the town where the infected might be kept apart and provided for all things convenient for their sustenance and care; and the same should be done in London. Mention was also made of a little book set forth in the time of the great plague and last year printed again which contained divers good precepts and orders and which might be recommended by the minister of every parish to all housekeepers. Finally, on this occasion, the council required the suppression of all who sold old apparel, a trade in no wise to be suffered in time of infection.

Perhaps because of these constant exhortations the mayor and alderman issued a most elaborate set of orders for removing such enormities as not only continued but increased the plague and disorders of the city, and for providing for the poor and setting them to work. Aldermen or their deputies were to charge churchwardens, constables, parish clerks and beadles to inquire what houses were infected; they were also to visit the ward often to see orders observed, especially touching cleanness in the streets, to appoint surveyors monthly in every parish, to see that certificate be made to them concerning the infected houses, to give charge to all teachers of children that they permit no children to come to their schools from infected houses, especially until such houses have been free for twenty-eight days, and that none keep a greater number than their rooms shall be thought fit to contain. Surveyors were to see that the orders for the sick were executed daily and diligently, and they were to appoint purveyors of necessaries for infected houses and to deliver them reed rods to carry and see that none other resort to these houses. Constables every day were to bring notice in writing to the aldermen what houses were infected. The constable and the churchwarden were to have in readiness women to be providers and deliverers of necessaries to infected houses and to attend the infected persons; these were to bear reed wands, so that the sick might be kept from the whole, as much as possible. The constable and the beadle were to inquire what houses were infected and to see daily that papers remained upon doors twenty-eight days or to place new ones. Clerks and sextons were to understand what houses were infected, to see bills set upon the doors of houses infected, and to suffer no corpses infected to be buried or remain in the church during prayer or sermon, and to keep children from coming near them. Scavengers and rakers were to see the streets made clean every day saving Sunday and the soil to be carried away, and to warn all inhabitants, against their houses to keep gutters clear from filth that the water might have passage. Every official was to kill dogs and other animals loose upon the streets or lose his place.

Not only, however, were various responsibilities placed on officials, but householders were likewise to aid in checking the infection. Houses having some sick though none died, or from which some sick had been removed, were infected houses, and were to be shut up for a month, and the whole family to remain twenty-eight days and to keep shut the lower rooms for the like space. One member was to go out for provisions; no

clothes were to be hanged in the street. As earlier, those having wells were to pour ten buckets full into the streets twice a day, every evening at eight o'clock the streets and gutters were to be made clean, the water not swept out of the gutter nor the streets made over-wet but sprinkled. The houses infected and the things in them were to be well aired, and no clothes or things about the infected persons were to be given away or sold but were to be destroyed or sufficiently purified. Owners of houses infected might depart within the month to their houses in the country or to any other house in the city without being shut up, so that they abstained from returning to the city, or from going out of the house in the city, for a month. None were to allow dogs out unled or within, howling and disturbing neighbors. No one was to visit infected houses but such as belonged to the house or was licensed to do service. Dunghills and bearhouses in the street were forbidden. Persons consenting to the pulling down of the words, "Lord have mercy on us," were to be restrained double time and the "taker away" was to be imprisoned for eight days. Meetings were prohibited.

The magistrates also appointed two viewers of dead bodies and two viewers of the suspected sick. These viewers were required to report to the constable, who in turn reported to the clerk, who went to the chief of clerks, all upon pain of imprisonment. False reports by the viewers called for standing in the pillory. A loss of pension was suffered by those who refused to do their duty. Diligent care was to be had to the mending of the pavements, principal pavers were appointed to survey the needs, especially in gutters, and the dwellers against such were forced to mend the breaks. If it was feared that the plague increase, plays might be restrained. Skilful and learned physicians and surgeons were to be provided to minister to the sick. The vagrant, masterless and poor people were to be sent to St. Thomas or St. Bartholomew's hospital, there to be first cured and made clean, and afterwards those not of the city to be sent away according to the statute, and the others to be set to work, in such trades as are least used by the inhabitants of the city, for the getting rid of the vagrants and loiterers who spread the infection. All masterless men who lived idly in the city without any lawful calling, frequenting places of common assemblies, as theaters, gaming-houses, cockpits, bowling alleys and such other places, might be banished from the city according to the laws in that case provided. All these orders the aldermen and their deputies were every one in their place to see performed, both in themselves and others, and in cases of doubt to yield their opinions and give directions.

Meanwhile, throughout other parts of the country preventive measures did not fail to make an appearance. During the Stourbridge Fair, the gates of the colleges at Cambridge were closed and no students were permitted to attend the fair. At Winchester, the visitation being dreaded, the authorities ordered the strictest inquiry to be made about foreign persons coming from any infected place, each of the town's six gates having a warden on duty. Shortly afterward, at Newcastle, although it had been customary to let the colliers out of the city early in the morning for their work, during the pestilence the magistrates put a stop to their going and coming; the colliers in the time of plague had to dwell beyond the walls. Moreover, men were warned to keep in their dogs and swine, and ducks were not allowed in the public pond because they too were suspect as plague carriers.

As the plague continued into 1594, it was observed that great inconveniences grew daily by the erecting of new tenements within London, Westminster and the suburbs, which much caused the infec-

tion by reason of the multitude of poor people that inhabited them, many dwelling together in one small space. The preceding Parliament had sought the reformation of these inconveniences, but now, seeing that the greatest number of plague deaths occurred in those houses pestered with inmates, the mayor and the aldermen were commanded to order that no new persons should be admitted to those tenements in the room of those that had died. A final precaution of 1594 that may be mentioned was the building of a pesthouse at London, but unfortunately its accommodations were totally inadequate and the city did not see fit to enlarge these all too limited facilities in the succeeding seventy years.

During the remainder of the sixteenth century there was no such wide-spread epidemic as characterized the years 1592–94, yet in various parts of England men continued to die of the pest and various precautions still operated. In 1596 the council sent letters to the justices of Middlesex and Surrey to restrain the players from showing any plays or interludes in the usual places about the city of London, fearing lest assemblies of people increase the contagion. At the election of the magistrates of Newcastle in the autumn of 1597 "rushes were spread thickly about the floors of the hospital and the sweet-scented herbs . . . . more lavishly strewn than was wont. The ceremonies ended, the burgesses, not to be balked of their accustomed feast of geese, made it to proceed without interruption, there being burnt during the whole time certain perfumes whose vapours, penetrating every nook and corner of the place, lulled the festive crew into a belief of temporary security." At Penrith in northern England during the visitation of 1598 outsiders refused to bring their commodities into the town market; the inhabitants therefore were under the necessity of meeting them halfway where a kind of quarantine was performed. No outsider touched the money used by the townpeople until it had been put in water from which it was extracted without the fingers touching it.

Before concluding this sketch of plague medicine it may be briefly emphasized that in contrast to the following century the plague of the sixteenth century did not stimulate any great body of pamphlet literature, and thus we are deprived of that immensely informing body of sources which prominently featured later visitations. Yet a few tracts did appear, to reveal that, whereas officials looked mainly to prevention and restriction, doctors were perhaps most inclined to concentrate on cures. These tracts contained a mixture of popular prejudice that bordered on folklore nostrums and at the same time a considerable amount of what modern health officials would describe as common sense. If they do not add a great deal to the thesis presented here they do round out the story of sixteenth century plague medicine.

In 1586 Thomas Cogan published "The Haven of Health: chiefly made for the comfort of students, and consequently for all those that have a care of their health, amplified uppon fine wordes of Hippocrates, written Epid. 6. labour, meate, drinke, sleepe, Venus." This tract, reprinted in 1589, came out in a second edition in 1596 and was reprinted in 1605 and in 1636. Cogan, a "Maister of Artes and Bachelor of Phisicke," advised that in order to escape the pestilence people should always take in their hands "an orange, or a posie of rew, or mint, or balme." He emphasized that against nature "Phisick can not prevayle; when nature will no longer worke, then farewell phisick. . . . The phisician may do his endeavour, but the successe is in God." Moreover, Cogan insisted that "among all things that purifie the ayre, either within the house or without, none is better than fire."

Some years later Simon Kellaway

wrote "A Defensative Against the Plague," containing two parts, the first how to preserve from the plague, the second how to treat those who were infected. The causes of the plague were great and unnatural heat and dryness or by contrast great rain and inundations of water, great store of rotten and stinking bodies lying unburied which corrupted the air so that corn, fruits, herbs and waters were infected, dunghills, filthy and standing pools of water, and the thrusting a great number of people into a close room, as in ships, common gaols and in narrow lanes and streets. But for the most part it came from clothes and the like that had been used about some infected body; and it might also come from dogs, cats, swine and weasels.

Certain signs foreshadowed the plague, as when the spring time was cold, cloudy and dry, the harvest stormy and tempestuous, with mornings and evenings very cold and at noon extreme heat. Other prophetic signs were comets, many frogs at the beginning of harvest and toads with long tails creeping on the earth, all of which showed the air to be corrupt. Also when young children flocked together in companies, and, feigning one of their members to be dead, solemnized the burying in mournful sort, the plague was likely to appear.

The plague threatening, the magistrates should command that no stinking dunghills be allowed near the city and should keep the streets sprinkled and cleansed from all filthy things, especially in hot weather. Where the infection was entered they should order fires to be made in the streets every morning and evening, wherein should be burnt frankincense, pitch or some other sweet thing. They of course should suffer no dogs, cats or pigs to run about the streets and see to it that all excrements and filthy things voided from the infected places be not cast into streets or into sewers. No surgeons or barbers that let blood should cast it into the streets or rivers, nor should vaults or privies be emptied therein, for that was a most dangerous thing. All innkeepers should clean their stables every day and cause the filth and dung therein to be carried out of the city, for by suffering it in their houses as some used to do a whole week or fortnight, it putrefied so that when it was removed there was such a stink as was able to infect the whole street. Magistrates should command that no hemp or flax be kept in water near the city or town, for that will cause a very dangerous and infectious savor. Finally, they were to take special care that good and wholesome victuals and corn be sold in the markets, and to provide that no want thereof shall be in the city, for there was nothing that more increases the plague than want and scarcity of necessary food. The remainder of the book contained receipts for perfumes, pomanders, preservatives, purges, cataplasms, powders, unguents, and the like for the various occasions of the plague, with directions for its prevention and cure.

Shortly afterward there appeared a little book, "Present Remedies against the Plague," reprinted again in 1603, which showed sundry preservatives through the use of wholesome fumes, drinks, vomits and other "inward receits" and also the "perfect cure" of those already infected. The author, "a learned Physition," writing for the better health of his country, gave remedies "for ayring your roomes," roots "to smell to" and to "taste or chewe in the mouth," and the medicines that would "procure sweat" or a "special vomit." He also advised people to keep their houses, streets, yards, sinks and ditches sweet and clean from all standing puddles, dunghills and corrupt moistures, and not let dogs, "which be a most apt cattle" to carry the infection, come running into the house. In particular, he declared that rooms should

be aired with charcoal fires, made in stone pans or chafing dishes, and not in chimneys. As for other remedies, he recommended a favored preservative, which involved chewing the root of angelica, setwall, gentian, valerian or cinnamon, and also the eating of a toast of bread, sprinkled with red rose vinegar, buttered and powdered with cinnamon, and eaten fasting, and finally the drinking of rue, wormwood, and scabias, steeped in ale a whole night and drunk fasting every morning, or the water of *carduus benedictus,* or *angelica,* mixed with *mithradatum.*

These remedies, however, should not be considered the full measure of plague medicine, for by the end of the sixteenth century the plague was oftenest regarded neither as symptomatic of God's wrath nor as an incomprehensible visitation to be propitiated through the agencies of folklore but rather, especially by those in a position to make their attitude felt, as a phenomenon which could be avoided or at least regulated and restricted. The abundance of official orders constitutes the best evidence that in the matter of the plague the sixteenth century was not unaware of its medical problems. These ordinances answer the contention that the plague was met only by superstitious incantations, weird combinations of herbs, toads and excreta, or the confession that nothing could be done about it. While sanitary arrangements were far from perfect, a casual stroll through a modern community will indicate that present-day standards of judgment are quite insecure. The miasmic odors of open sewers, the exposed garbage dumps, the endearing caresses heaped upon household pets which have swept up the city streets in their passage, the foul air and a dozen other conditions reveal no utopia of sanitation in the twentieth century. In any case it is enough for us to appreciate that the authorities of sixteenth century England made persistent and intelligent efforts to halt a scourge that carried with it such diverse and far-reaching effects as did the plague.

WORM PARASITISM IN DOMESTIC ANIMALS

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Some General Considerations of Helminth Parasitism

Parasitism is an ancient but not an honorable partnership between two species of animals, one of the partners, the parasite, getting all that he can from and contributing nothing but grief to the other partner, the host. Since parasitism due to worms is wide-spread in all groups of vertebrates, it may be assumed that the association between a worm parasite and a host is a biological partnership that, in most cases, is not fraught with too great a hazard for the host under natural conditions as opposed to man-made artificial conditions.

Under natural conditions the parasite is in a rather precarious situation so far as self-perpetuation is concerned. Parasites perpetuate themselves through eggs or larvae which issue from eggs. Once they are eliminated from the host's body the eggs or larvae may be destroyed by inimical environmental influences, such as unfavorable temperature, strong sunlight and drying, before they have undergone any development or while they are developing. If the eggs or larvae escape these and other destructive influences, they may not be taken up by a host in which they can complete their development or they may not be taken up by any host, in which case they succumb sooner or later. In the case of parasites which require an intermediate host for the completion of the life cycle, the chances of survival become increasingly smaller because the egg or larva must reach the proper intermediate host, which, in turn, must establish the right sort of connection with the proper final or definitive host. Only the worm parasites that are transmitted by blood-sucking arthropods have overcome to a large extent the risks attendant upon the completion of the life cycle. In short, the life of a parasite may be a happy one while it lasts, but the continuity of any species of parasite through centuries in which parasitism has existed might have involved at least occasional risks of extinction for some species of parasites. Considering the great hazards involved in the completion of the life cycle, a high intensity of infestation with parasitic worms is largely the result of a restricted range of the host.

Assuming that under natural conditions species of parasites have not become extinct, as a rule, one explanation for their persistence is probably their extraordinary reproductive capacity. It is doubtful whether any other ecological group of animals has a greater reproductive capacity than that exhibited by the parasitic worms. The latter live in a sheltered environment, rich in food supply. The energy which free-living animals expend in satisfying the fundamental instinct of self-preservation by securing food and in escaping annihilation by enemies and by the destructive forces of nature, is thus available to the parasite to be utilized for some other purpose. That parasites utilize much of their energy in reproduction is evident even to the novice in parasitology. The abundant reproductive capacity of parasites thus compensates to a large extent for the uncertainty that the eggs or larvae of a particular species will reach the proper host at the proper time, and virtually assures at least the perpetuation of the hundreds of species of worms which parasitize the animals which man raises for pleasure or profit.

Under conditions which can not be regarded as natural, such as those involving the customary animal husbandry operations, even the slightest risk of extinction attendant upon the parasitic mode of life has been largely, if not entirely eliminated. In fact, the husbandman, by restricting the range of the host animals in order to feed them and otherwise care for them, has created an ideal situation for the perpetuation of parasites. He has become a breeder not only of live stock but inadvertently also of live-stock parasites. By confining his animals to increasingly smaller areas, the stockman has transformed the host-parasite relationship from what might have been at one time a more or less normal biological relationship into a relationship which has become pathogenic to the host because of the high intensity of parasitic infestation of meat food and other animals raised under farm conditions.

One of the great surprises which the parasitologist receives on his first visit to the tropics is the general lack of abundance of parasitic worms in domestic animals other than household animals. The tropical environment, with its equable climate and usual abundance of moisture, offers, theoretically at least, ideal conditions for a thriving parasitism. That tropical conditions are favorable to the perpetuation of worm parasites is evident from the fact that the incidence of such parasites in human beings and household animals, such as dogs and cats, is high in the tropics. Therefore, the general low incidence and low intensity of parasitism in live stock in the tropics must be accounted for on a basis other than environmental. Actually, the relative scarcity of live-stock parasites in the tropics is due to the relative scarcity of live stock. With the increase in the numbers of live stock and the introduction of customary animal husbandry practices, parasitism will assume increasing importance in the tropics, this being evident already by occasional reports of intense and even fatal parasitic diseases of horses, ruminants and hogs in tropical countries, the general clinical picture of these parasitic diseases in the tropics being essentially that observed in temperate zones.

Assuming, therefore, that the high incidence and high intensity of parasites observed in live stock in practically all sections of the United States has resulted for the most part from a gradual restriction of range in the face of an increasing live-stock population and from the use of more or less permanent pastures which have become saturated with the eggs and larvae of parasitic worms, it is not surprising that parasitism in live stock has become an economic problem of great magnitude and importance in this country. That this problem must be kept in mind and taken into consideration in all attempts to formulate sound husbandry practices will become evident from the following brief review of the essential facts regarding some of the more important internal parasites of live stock in this country.

Parasites of Swine

Swine harbor many species of internal parasites, of which the following are among the most injurious:

Intestinal roundworms or ascarids: The large intestinal roundworm or ascarid occurs as an adult in the small intestine, where it attains a length of about an ordinary lead pencil. Swine become infested with this parasite as a result of swallowing the infective eggs of the worms; the eggs are eliminated with the droppings of infested swine and reach the infective stage in about three weeks under favorable conditions. One of the most interesting discoveries in connection with these roundworms came to light about twenty years ago. Up to that time it was generally believed

by parasitologists that the swine roundworm egg hatched in the stomach or intestine of its host, and that the young worm which issued from the egg developed to maturity without straying from the lumen of the gut. In 1916 it was shown for the first time that, after hatching, the ascarid larva penetrated the wall of the intestine, migrated with the blood stream to the liver and thence to the lungs and finally returned to the intestine by migrating along the bronchioles, bronchi, trachea, pharynx, esophagus and stomach. In the course of these investigations it was noted that if many larvae went through the lungs at the same time they produced symptoms and lesions of pneumonia. These findings placed the ascarid in the category of a serious pathogen, endowed with far greater capacity of doing harm than had ever before been suspected. On getting into the intestine the second time, the ascarid larvae settle down and develop to maturity in the course of about two months. The mature females produce astonishingly large numbers of eggs which pollute the pastures in which the infested host animals are kept, thus paving the way for infection of young pigs which are kept on such pastures.

It has been shown that one female ascarid may discharge about one quarter of a million eggs in a single day. If the egg-laying period of a female should last one hundred days, a pig harboring about twenty-five female ascarids would discharge during this period about 625,000,000 eggs. In the light of such figures it is not surprising that pigs raised on permanent pastures acquire exceedingly heavy ascarid infestations at a period of life when they lack the ability to successfully cope with such infestations. The net result is a serious setback, from which complete recovery is not made, or death, in cases of extremely heavy infestation.

Kidney worms: The swine kidney worm is more or less unique among parasites in that it has no communication with the alimentary canal, its eggs being discharged to the outside with the urine. The adult worms occur in burrows in the kidney fat and in the kidney itself; the worms in the kidney fat establish channels to the ureter, which they puncture, thus affording an outlet for the eggs to the outside.

Kidney worm eggs develop on the ground rapidly and hatch in a day or two under favorable conditions. In about five days or longer, depending on the temperature of the environment, the larvae attain the infective stage, following two molts. The infective larvae can enter the bodies of swine either through the skin or through the mouth; however, regardless of the portal of entry, the larvae migrate to the liver, and those that extricate themselves from this organ do so by perforating the liver capsule. The worms which fail to escape from the liver become encapsulated. From the surface of the liver the incompletely grown worms migrate to the perirenal fat, which they perforate rather easily. As already stated, some of the worms enter the kidney. The entire cycle in the host proceeds rather slowly, about six months being necessary, as a rule, for the attainment of sexual maturity.

Nodular worms: Nodular worms occur as adults free in the lumen of the large intestine. The eggs of these worms are discharged with the manure of infested swine. The eggs hatch on pastures and the larvae develop much in the same way as do kidney worm larvae. Infestation results solely from swallowing the infective larvae with contaminated feed or water. Hogs which root among trash and debris are likely to pick up heavy infestations with nodular worms, since the larvae seek shelter among such debris, where they survive for relatively long periods.

Lungworms: Lungworms are acquired by hogs as a result of swallowing infested earthworms which are brought to the surface by rooting. Earthworms in turn acquire this infestation as a result of feeding on swine manure. Hogs infested with lungworms may eliminate lungworm eggs over a period of several months. In an experimental infection, involving the feeding of only 500 lungworm larvae, isolated from earthworms, the writer estimated an output of over 3,000,000 lungworm eggs with one day's droppings at the height of egg production. An infestation of the sort produced by the writer experimentally can not by any means be regarded as a heavy infestation. A single infested earthworm collected by the writer in a hog lot was found to harbor approximately 2,000 larvae. A hog which swallows a single earthworm so infested, and a single rooting expedition might reward the rooter with many earthworms, would acquire a sizable infestation, sufficient to produce in the lungs extensive pneumonic areas.

Thorny-headed worms: The thorny-headed worm of swine, like the lungworm, also has a complicated life cycle, in the course of which the eggs of the parasite, eliminated with the hog's droppings, develop in May-beetle larvae if the latter feed on swine manure. Swine become infested as a result of swallowing infested May-beetle larvae.

Stomach worms: Among the parasites which contribute to a large extent to the picture of unthriftiness in swine are the three species of stomach worms, of which one species, the red stomach worm, has a direct life history, similar in some respects to the life history of nodular worms; the remaining two species of swine stomach worms have indirect life histories, species of dung beetles serving as intermediate hosts. The beetles pick up the infestation as a result of swallowing the eggs with swine manure; swine become infested by swallowing infested beetles. The stomach worms that are transmitted by dung beetles produce marked pathological changes in the stomach wall, characterized by a conspicuous catarrhal inflammation.

Controlling Swine Parasites

From this brief review of the mode of transmission of some of the more common parasites of swine, it is evident that the parasites which have been discussed, excluding the kidney worm, are transmitted either directly through the manure or indirectly through intermediate hosts. In either case the manure is the ultimate source of the infestation, and control measures must be based to a large extent on manure disposal or on some other procedure which will protect pigs from contamination with manure of older hogs.

Because of the conditions under which swine are usually raised, parasitism has become a serious problem in swine husbandry operations. Much of the stunting of pigs, respiratory diseases early in life, loss in condition, general unthriftiness and condemnation under meat inspection procedure are due to parasitic infestation. While these losses can not be estimated accurately in terms of dollars and cents, the aggregate losses, considering the various kinds of swine parasites definitely known to be injurious, must run into several million dollars annually.

Several years ago investigators of the Federal Bureau of Animal Industry determined that the losses from kidney worms in a single relatively small packing house located in one of the southern states amounted to about $50,000 a year. Practically all the livers, kidneys and kidney fat of hogs raised in infested areas and killed at that abattoir were condemned, and the loins of about 10 per cent. of the hogs had to be extensively trimmed under federal meat inspection

procedure. In the same plant it was estimated at one time that condemnation of the large intestine of hogs because of lesions due to a certain species of nodular worm would show an annual loss of about $25,000, this estimate being based on figures available at the time that the calculation was made. Considering the fact that more than one third of the hogs which are raised in the United States are raised in the South and that the two species of worms above mentioned as responsible for the losses under meat inspection procedure are more prevalent in the South than elsewhere, the total losses to the live-stock and meat industries of the South from these parasites alone must reach a rather significant figure.

In addition to the loss under meat inspection procedure, it is important to consider the direct loss to the farmer. The latter loss is practically impossible to estimate; that it represents a tangible loss in the form of stunted growth and unthriftiness is evident from the following considerations.

About 10 years ago the Federal Bureau of Animal Industry initiated a research project in the South, the purpose of which was to investigate the extent and degree of swine parasites and to develop practical control measures, with special reference to kidney worms. This project involved a searching investigation on the life history of the swine kidney worm, a study of the resistance of the eggs and the larvae of this parasite to various environmental influences, a study of the distribution of the larvae on pastures, including a consideration of their duration of life under various conditions and similar more or less technical problems.

As a result of these investigations and in conformity with the facts elucidated, there was formulated a method of control, involving for the most part modifications in swine husbandry practices of a sort which would subject kidney worm eggs and larvae to the destructive influences of sunlight and drying. The practical arrangements, developed under farm conditions, involved a bare strip at one end of the pasture, the feeding pen for the sow, the creep for the pigs, the watering facilities and the shelter houses being placed on this bare area. Provision was made also for bare narrow strips along the fences, wherever practical. Under these arrangements most of the urine voided by the hogs reached the bare ground where the kidney worm eggs that are eliminated with the urine were exposed to the lethal action of sunlight and drying. Under these arrangements, which were coupled with sanitation in the broad sense, precluding the accumulation on the pasture of corncobs and husks and other litter which afforded a haven to kidney worm eggs and larvae, it was possible to control kidney worm infestation to a large extent. The success attending the practice of the precautions mentioned varied to a large extent with the degree of adherence to details of sanitation, with the result that a strict adherence to these details yielded practically 100 per cent. results. These procedures are now being adopted not only in the region where they were shown to be practical and profitable, but also in other sections of the South.

The losses among swine due to stunting and unthriftiness as well as to the losses because of kidney worm lesions under meat inspection procedure have been practically eliminated in those cases in which the sanitary procedures were followed. Moreover, these procedures were found to be effective in controlling ascarids and lungworms as well as kidney worms and they were at least partially effective in controlling nodular worms.

In brief, the problem of swine parasite control, reduced to simple terms, involves sanitary arrangements of a sort

that will protect the pigs from acquiring the species of parasites harbored by the sows. Since the pigs must remain with the sow during the suckling period when their susceptibility to parasites is at its height, any practical arrangements that tend to destroy the eggs and larvae of parasites on pastures will reduce the potential and actual infestation and thus help to tide over the pigs during their most critical period in life.

Parasites of Horses

Horses are among the most heavily parasitized domestic animals as regards the number of species harbored and as regards the actual number of worms present in individual animals. Individual horses that are kept under sanitary conditions with regard to housing and fed properly may harbor several hundred worms, even when these host animals have but little access to pastures. Horses that are not properly cared for are veritable menageries of helminths and harbor thousands of worms, located for the most part in the digestive tract, but occurring also in other parts of the body, including practically all the thoracic and abdominal viscera, the blood system, in fact, practically all organs and tissues of the body. In the discussion which follows only the most important parasites of the alimentary canal will be considered.

Stomach worms: Three species of horse stomach worms of common occurrence in this country are transmitted by various species of flies, including biting as well as non-biting flies, the flies becoming infested in the maggot stage while feeding on horse manure. The adult flies infect horses as a result of feeding on the moisture of the lips and nose of these animals, the heat of the horse's body stimulating the larvae to escape from the flies onto the lips or into the nose. Since these larvae are very active, they probably wriggle into the mouth and nostrils, and thus reach the stomach, where they develop to maturity. The stomach worms attach to the wall of the stomach, and one of the three species, *Habronema megastoma,* produces conspicuous tumors on the stomach wall, the worms being located within these tumors.

Ascarids: The horse ascarid, about as well and as unfavorably known as the swine ascarid, has a life history essentially similar to that of its first cousin. This life history has already been outlined and will not be repeated again. In experimental infections of foals with ascarids, the host animals showed rise in temperature and coughed considerably. That these symptoms were due to the migration of ascarid larvae through the lungs was clearly demonstrated in a post-mortem examination of the experimentally infested foals; the larvae of ascarids were actually discovered in the trachea, this location corresponding to the route which the larvae follow on their return journey to the intestine.

Strongyles: The worms in horses which are best known to veterinarians and farmers, because of the injuries which they inflict, are the strongyles, of which there are about sixty known species, the habitat of these worms being the cecum, ventral and dorsal colon. Some of the strongyles are well known because of their size, their more or less reddish color and their firm attachment to the wall of the gut. Other strongyles, because of their smaller size, inconspicuous color and the fact that they are not found attached to the wall of the gut during necropsy, are perhaps not so well known. However, all the strongyles of the horse are potentially pathogenic and several species have an established reputation for being veritable racketeers. The worst offenders are not merely content to rob the host of his precious life blood, but they injure him extensively by invading many vital organs, including the liver, spleen and kidneys; one

species, *Strongylus vulgaris,* is a serious pathogen and is responsible for the production of aneurisms of the anterior mesenteric artery. These aneurisms interfere with the blood supply to the gut and are responsible for colics which reduce the working efficiency of horses.

Strongyles have simple life histories; the eggs which are eliminated with the horse's droppings develop on pastures in a day or two under favorable conditions, and the newly hatched larvae become infective three or four days later under equally favorable conditions. The larvae are very resistant, however, to adverse environmental influences, being capable of surviving for long periods under the influence of prolonged drying and severe sub-zero weather.

Horses acquire an infestation with strongyles as a result of swallowing the infective larvae with green feed, dry feed or as a result of drinking water contaminated with such larvae. Many of the details of the subsequent migration of the larvae in the body of the host have not been ascertained. It is certain, however, that some species of strongyles wander extensively in the horse's body and get into situations from which they can not extricate themselves in order to resume their migration to the large intestine. As a result of these straying habits, the larvae leave behind a trail of lesions to vital organs, these injuries having a more or less pronounced effect on the host.

Controlling Worms in Horses

It has been shown in a series of controlled experiments with mules in Louisiana that the administration of anthelmintics known to be effective in removing strongyles from horses was followed by a restoration of normal working capacity in animals which had been more or less incapacitated for some time prior to treatment. A series of similarly incapacitated mules, not treated for the removal of worms, continued to suffer from colic and remained incapable of working at a normal rate. Graham in Illinois had remarkable success in restoring to usefulness a horse which had been condemned by the Army, by resorting to anthelmintic medication. This animal not only gained weight, showed a steady increase in hemaglobin content and red blood cells, but underwent an amazing transformation from a weak, emaciated, decrepit animal, with a rough coat, tucked-in flanks and sunken eyes, to a spirited mount that any rider would be glad to possess. These are but a few instances of the effect of parasites and especially of strongyles on horses.

In view of great resistance of the larvae of horse strongyles to inimical environmental influences, the control of horse parasites by sanitation alone is not practical and is usually unsuccessful. Horse parasite control must involve a combination of stable and pasture sanitation, pasture rotation as often as available pastures permit, and periodic treatment for worm removal.

Stable sanitation is largely a matter of proper disposal of manure in order to remove potential infective material. The spreading of horse manure on pastures to which horses might have access even a year or two later is equivalent in its results to an intentional dissemination of infective larvae. Pasture sanitation presents far greater difficulties than stable sanitation. The removal of manure from pastures is actually in progress, however, on certain farms devoted to the breeding of Thoroughbreds. Such procedure is too expensive and too impractical, however, for the average farmer and can be recommended only in special cases.

The Zoological Division of the Bureau of Animal Industry has developed a manure box for temporary storing and rendering a horse manure free of live worm eggs and larvae. The box has

double walls and a double floor and is provided with a well-fitting lid. Work which was conducted by the writer in collaboration with some of his associates in the Bureau of Animal Industry has shown that after about two weeks' storage, the manure is practically free of worm eggs and larvae, the few that survive in cold pockets in the box being negligible in comparison with the thousands that perish. The destruction of life in the eggs and larvae is brought about by the self-heating which horse manure undergoes, the temperatures attained in the process of self-heating being more than adequate to kill the eggs and larvae.

In view of the rather long storage period required for the accomplishment of the desired results, the Zoological Division has been experimenting with the sterilization of manure, so far as parasites are concerned, by means of live steam at approximately 15 pounds pressure. These experiments are still in progress, but the indications are that the manure subjected to steam as mentioned can be rendered helminthologically sterile in the course of an hour or so.

The subject of rotation of stock will be discussed in connection with the parasites of domestic ruminants. Rotation of pastures, so far as controlling horse parasites is concerned, is of rather limited value, considering the longevity of horse strongyle larvae even under adverse environmental conditions. Treatment for worm removal offers a practical solution to the problem of horse parasite control. Removal of worms affords the infested animals relief from the drain of the infestation and cuts down the supply of worm eggs at the source. Treatment for worm removal is, therefore, a part of prophylaxis.

Bots: Bots are the maggots of certain flies (Gastrophilidae) which occur in the gastro-intestinal tract of equines. They are included in this discussion solely for the purpose of rounding out the picture of gastro-intestinal parasitism in horses.

In recent years the control of bots in horses has attracted considerable attention, perhaps because the average farmer and horseman knows more about bots than about strongyles. Bots injure the stomach and duodenal wall to which they are attached and contribute to the picture of unthriftiness that is so commonly associated with parasitic infestation. Moreover, the adult botflies annoy horses and are responsible for runaways.

Briefly, bots develop from eggs deposited on and glued to the hair, each species of bot having its preference for a certain part of the body on which the eggs are deposited. The common bot, which occurs in all parts of the country, glues its eggs usually to the hair of the legs; the chin bot glues its eggs to hair of the jaw, and the nose bot glues its eggs to hair on the lips. The eggs of the common bot hatch under the influence of moisture and heat, the horse supplying the moisture and heat while licking itself and the larvae being carried to the mouth by the tongue. The eggs of the chin bot hatch without moisture, the larvae crawling into the mouth after hatching. The manner of the hatching of the eggs of the nose bot has not been ascertained. It has been shown recently that once the newly hatched bots reach the mouth, the larvae penetrate into the mucosa of the tongue and cheeks and that, in the case of the common bot, the larvae do not reach the stomach until about twenty-one to twenty-eight days after they have been taken into the mouth.

On the basis of these findings the rational procedure with regard to treatment, when only one treatment is given in the course of a year, is to administer carbon bisulfide one month after the first killing frost. Presumably the adult flies are killed by the frost, and by deferring

treatment for a whole month after the killing frost, the larvae that are already present in the mucosa of the tongue and cheeks will have reached the stomach. Thus, the maximum results can be attained by a single treatment if the aforementioned recommendation is followed.

Parasites in Ruminants

Cattle, sheep and goats are seriously affected by worm parasites. Sheep, in particular, suffer severely from parasitic infestation, the latter being the major drawback to successful sheep husbandry. The control of parasites of domesticated ruminants thus constitutes a problem of major importance to the owners of these animals.

Stomach worms: It is hardly necessary to emphasize the pathogenicity of the stomach worm to sheep. In nearly all sections of the United States, this worm is the chief obstacle to successful sheep raising. A slight initial infestation in several sheep may produce heavy infestations in large flocks in the course of a single season. This is brought about as follows: The eggs of the parasite are eliminated with the feces of the host; during the summer months, the eggs hatch in a day or so. The larvae undergo their preparasitic development on pastures in a few days. The infective larvae climb up grass stalks and blades, when sufficient moisture is present to enable them to move in the films which settle on the grass. During rains, fogs and dews, the larvae become very active in their upward migrations, and this brings them into favorable situations to be swallowed by sheep while the latter are grazing. In about three weeks after the larvae are swallowed, the worms attain fertile maturity and the females begin to deposit eggs, which are eliminated with the sheep's feces, thus starting the life cycle of the parasite once more.

As an example of the tremendous fertility of the stomach worm and of the rapidity with which an infestation with this parasite can be developed to enormous proportions, as judged by the quantity of eggs which the worms produce, the following case, reported by Stoll, may be cited. Twin lambs, about eleven weeks old, raised by hand since birth, kept under conditions which precluded infestation with stomach worms and other parasites and actually found to be free from parasites so far as negative findings on microscopic inspection of the feces afford evidence, were placed on a pasture on which no sheep or other ruminant had been kept for at least two years and which no sheep had traversed during that period. It is reasonably safe to assume that this pasture was free from larvae of stomach worms. One of the lambs was given forty-five stomach worm larvae by mouth. This lamb began to discharge stomach worm eggs nineteen days after the larvae had been fed, the egg output increasing gradually and reaching a peak of 13,600 eggs per gram of feces about twelve and a half weeks after the infection was started. The second lamb, to which no larvae were fed and which presumably acquired its infestation from the larvae which hatched from eggs discharged by the first lamb, began to show eggs in its feces fifty-four days after the first lamb was infected. While the second lamb did not show as high an egg output as the first one, it eliminated 10,900 eggs per gram of feces at the peak of egg production. The estimated total output of stomach worm eggs by these two lambs at the peak of egg production was 8,770,000 eggs in a single day by the first lamb and 7,260,000 eggs in a day by the second lamb. This maximum was gradually attained and the output then gradually declined.

In the light of such evidence, it is clear that slight initial infestations with stomach worms deserve serious consider-

ation and warrant treatment, since apparently unimportant infestations may pile up tremendously in the course of a single summer and lay the basis for serious losses among large flocks.

While the pathogenicity of the stomach worm to sheep is generally recognized by farmers, it is important to remember that stomach worms are also of common occurrence in goats and calves and that these animals are by no means unaffected by infestations with these worms. Treatment and control measures for stomach worm infestation should not stop with sheep if goats or calves or both of these groups of ruminants are known to be infected.

Controlling Stomach Worms

The control of stomach worms involves a combination of treatment and rotation of pastures and of stock. In view of the great fecundity of stomach worms and the rapidity with which their life cycle is completed, no practical system of rotation, effective for the control of these parasites, has been devised, and it is exceedingly doubtful that it will be possible to control haemonchosis in ruminants by prophylactic measures alone. Treatment alone and combination of treatment and rotation of pastures and of stock are both effective in controlling stomach worm disease to a point which makes sheep raising possible and profitable; but, under American farm conditions, control measures which have not included treatment have usually been unsuccessful.

So far as concerns prophylaxis for stomach worm infestation by rotation of pastures and of stock, these measures are indicated and should be used wherever possible. In connection with rotation of pastures it is important to remember that areas not occupied by sheep for a few weeks or a few months should not be considered free from stomach worm larvae. While many larvae doubtless succumb to unfavorable conditions, such as drying, freezing and other environmental influences, other larvae, more favorably located on a pasture, may survive for long periods, despite unfavorable conditions. The maximum survival period for the eggs and larvae is unknown, but it is conditioned by such variable factors as temperature, moisture and other external influences.

The obvious advantages in pasture rotation are a diminished concentration of the eggs and larvae because of their wider distribution, and the certainty that more or less of the infective material on pastures will die off while the latter are not occupied by sheep. So far as rotation of stock is concerned, sheep should not follow cattle or goats, and *vice versa,* because stomach worms and other species of roundworms of ruminants are transmissible from one host species to another. Pastures previously occupied by horses or swine are relatively safe for ruminants, and *vice versa,* so far as parasites are concerned.

Other Gastrointestinal Parasites of Ruminants

Cattle, sheep and goats harbor numerous species of injurious roundworms other than stomach worms. Hookworms, nodular worms, ostertagids, trichostrongylids, nematodirids and other species of strongyles are usually abundant in the gastro-intestinal tract of ruminants. Some of these parasites are decidedly pathogenic when present in large numbers and are potentially and sometimes actually as harmful as stomach worms.

These roundworms have life histories essentially similar to that of stomach worms and, for this reason, some of the control measures taken with reference to the latter will help to keep down infestations with various other nematodes which occur in the gastro-intestinal tract of ruminants.

Lungworms: Lungworm infestation in

ruminants is caused by roundworms which have a direct life cycle, infestation resulting from swallowing infective larvae which develop from eggs eliminated from the feces of infested animals; sheep are also affected by heteroxenous lungworms transmitted by land snails. In the absence of effective treatments for lungworms, the indicated control measures are rotation of pastures and of stock and isolation of infested animals to keep the parasites from spreading to unaffected animals. Infested animals that cough and show other symptoms of lungworm disease require nursing treatment to tide them over the critical stages of infestation.

Liver flukes: Liver flukes are responsible for heavy losses among domestic ruminants, sheep and goats suffering more severely than cattle from this parasitic infestation of the bile ducts. In certain areas sheep practically disappeared as a result of grazing on infested pastures. In past years the sheep population of certain European countries was decimated by liver fluke infestation, and in the absence of proper precautions to control this parasite, many areas in the United States, principally along the Pacific Coast, in the Rocky Mountain States, in the South and Southwest will become unsuitable for raising sheep. Cattle are less seriously affected than sheep and goats. However, infested cattle do not thrive and are rather difficult to raise to market condition. Moreover, the livers of flukey cattle are condemned under meat inspection procedure, this condemnation constituting a serious loss to the live-stock and meat industries, considering the value of beef livers in the human diet and more particularly in the treatment of anemias.

Each fluke is capable of producing about 100,000 eggs, which are eliminated in the feces of the infested host. The miracidium which hatches from each viable egg lives only a few hours unless it finds a suitable lymnaeid snail into which it penetrates. The development in the snail is rather complicated and involves a number of larval stages, the final developmental stage in the molluskan host being a cercaria which leaves this host and encysts on aquatic vegetation or floats freely as a cyst on the surface of water. A single miracidium can give rise to 150 to 320 cercariae, a single fluke in the bile ducts of sheep can give rise, at least theoretically, to as many as 32,000,000 cercariae, each cercaria being capable of developing into a mature fluke in a suitable definitive host. This is, indeed, a reproductive capacity run riot.

Control measures for liver flukes involve the destruction of aquatic snails by draining or filling of wet pastures or by killing the snails with chemicals. Drainage is the best procedure to adopt in regions where it is practical to do so. Where it is impossible to drain or fill wet pastures, the dangerous areas may be fenced off to prevent ruminants from having access to them. Where none of the above procedures appear practical, it is still possible to control liver flukes by means of copper sulphate. The crystals of copper sulphate may be dissolved in running water which flows over the snail-infested pastures. The crystals or powder of copper sulphate may be broadcast by hand or powder dusters over large areas. A dilution of one part of copper sulphate to 500,000 parts of water will kill snails in twenty-four hours.

Since the prevention of liver fluke infestation involves a modification of the environment where ruminants graze, objections have been raised to the control measures outlined in this paper. Some persons interested in the preservation of wild life and in retaining certain areas under primitive conditions see in the liver fluke control program a threat to the nation-wide wild life conservation

program. In so far as this objection is limited to control measures on the public domain, it can be sustained as having merit. The objection to the broad program of liver fluke control on privately owned agricultural land is without merit, however, and naturally meets with opposition from the owners of live stock. Man has a right to transform his environment as a measure of protection to himself and the animals which furnish food, clothing and power on the farm. This history of civilization is an almost uninterrupted story of the modification of ecological conditions to develop agriculture, build cities, construct roads, exterminate harmful and noxious animals and plants and otherwise transform man's primitive environment in keeping with the demands of an advancing civilization. In the final analysis, snails that transmit liver flukes to domestic ruminants are no more useful to mankind than are tsetse flies, mosquitoes, ticks, lice, fleas and a host of other disease-transmitting invertebrates that threaten the very existence of mankind and the beasts on which he depends for food and clothing.

Summary

Summarizing the essential facts which should be kept in mind in connection with the control of parasites and parasitic diseases of live stock, the attack on the parasites present in the host must be supplemented by an attack on the infective stages which are present in the host's environment. The latter involves such procedures as supplying clean pastures, rotation of pastures and of stock, special care of young animals to protect them from gross parasitism while they are still highly susceptible to the injuries which parasites inflict, proper disposal of manure to cut down pasture infestation, control of intermediate hosts, a sanitary water supply and similar hygienic procedures.

The complete eradication of worm parasites of live stock is only a theoretical possibility, but is an ideal worth striving for. The practical goal in livestock sanitation, so far as worm parasites are concerned, is control to a point which will cut down losses resulting from infestations with ascarids, stomach worms, kidney worms, lungworms, strongyles of various sorts and other injurious internal parasites. Considering the great fertility of parasites and the marvelous adaptations which these pests have developed to enable them to cope with their environment inside and outside of the host, even under unfavorable conditions, the reduction of the number of parasites to a point where they do comparatively little harm is a goal worth attaining.

COLOR AND PIGMENTATION

WHY THEY SHOULD INTEREST US AS BIOLOGISTS

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As a preliminary to the discussion of this topic, it seems worth while to orient ourselves by considering what we mean by color and pigmentation. This because there has been considerable confusion in the use of these terms, with some resulting confusion of thought.

By the color of an object, we mean the quality of the light which it transmits, if the object is transparent, or which it reflects from its surface, if the object is opaque. The rays which are not transmitted or reflected are absorbed. If all wave-lengths are absorbed equally and completely, we call the substance black; if they are absorbed equally but incompletely, we call the substance gray; if they are reflected equally and completely, we call the substance white. If the various wave-lengths of the incident light are absorbed unequally, so that only certain rays are reflected or transmitted, we call the substance "colored" in the narrower sense of this term. I must agree with those who prefer to restrict the term color, so far as practicable, to this differential absorption and reflection of the various components of white light. There are those, to be sure, who include black, white and gray among the colors, and are compelled, accordingly, to distinguish "chromatic" and "achromatic" colors. This would seem to be doing violence to our language. However, it is important at times that we should have some inclusive word covering both the colors and the shades of animals, and thus the continued use of the term "animal coloration," in this broader sense, seems inevitable.

Color, as is well known, may result either from the chemical constitution of an object or from certain physical properties of its surface layers. In the latter case, we are dealing with what are termed "optical colors." For the former I know of no very satisfactory term, unless we call such colors "chemical colors."

The word "pigment" is one which has not always promoted clear thinking. As commonly employed, the word is applied to a great variety of colored substances, though by no means to all. Since it is a word of Latin origin, based upon a verb meaning "to paint," we may fairly infer that it was originally applied to substances used as coloring matters. A pigment was something employed by man to color something else. On this basis, we should regard ferric ferrocyanide and red lead oxide, for example, as pigments, while many other colored substances, such as copper sulfate and potassium bichromate, would not be so designated. Or perhaps the two former are to be regarded as pigments only when they are actually used as such.

In biology, a new criterion seems to have been adopted. From applying the term pigment to something which we ourselves employ to color something else, the meaning seems to have been extended to include anything which chances to give color to anything else. And so we have a whole series of "pigments" in the blood and bile and urine, in addition to those externally visible ones which color the skin and hair and feathers.

The situation here is rather curious. The urine, for example, is a solution con-

taining many ingredients. One or two of these happen to be colored. Though present only in minute quantities, and of secondary importance physiologically, these colored substances have been given a unique status as "urinary pigments." It is difficult to see why, in their own right, they are entitled to be classed as pigments, since we do not employ this term for colored substances in general. They are pigments only by virtue of their giving color to something else—in this case the urine.

Again, it chances that those constituents of the blood of animals which are most actively concerned in conveying oxygen are more or less highly colored substances. Accordingly, there has emerged a considerable series of "respiratory pigments." That the colors of these substances, as such, bear any relation to the respiratory function I do not think is contended by any one. Nor is it contended, so far as I can learn, that a substance playing this rôle need be colored at all. Then why "respiratory pigments"? With all due deference to those who know infinitely more about the physiology of respiration than I do, I would suggest that the oxygen carriers of the blood be designated by some more appropriate term.

We seem to be departing less from strict etymological usage when we turn to those "pigments" which give color to the skin or its derivatives on the external surface of the body. These would seem to be present in the rôle of coloring matters and nothing else. Their function in determining the appearance of an animal would seem to be as indisputable as that of the artificial pigments with which our Indian braves formerly painted their faces, and our civilized ladies do at the present time.

However, even here, the use of the word "pigment"—I now refer only to the natural ones—has tended to introduce an insidious error into our thinking. We have been prone to make the unconscious assumption that these "pigments" were there in order to give color. It is difficult to divest the word of its teleological significance.

In the days before Darwin, the colors of animals, or some of them at least, were regarded by many as having been created for man's esthetic satisfaction. Darwin, Wallace and others directed our attention to the possible utility of animal coloration to the animals themselves, either by way of affording them concealment or giving them a warning aspect or producing a color-scheme calculated to charm the opposite sex. In any case, it was the appearance of the animal, as perceived by another seeing organism, which was the essential feature of the adaptation.

I would be one of the last to question the frequent utility of color, as such, to animals. I am more disposed than many biologists to believe in the supreme importance, at times, of concealing coloration. Any merely physiological or biochemical account of the origin of these pigments, divested of the ecological setting of the animals concerned, would be utterly inadequate in many cases. It would furnish no clue whatever to the distribution of color—the color patterns—of numerous animals, and least of all to the origin of the elaborate mechanism controlling the color changes of many others.

But there is surely no inconsistency in my following this declaration with an equally emphatic one to the effect that much, perhaps most, of the coloring of animals is a mere by-product of their metabolism, having no relation to ecological needs. Colored substances may or may not have a rôle to play in the economy of the organism. When they do, this rôle may or may not have anything to do with the animal's external appearance. In any case, we must not confuse the question of the utility of a

given substance which chances to be colored, and the utility of the visible color which this imparts to the animal possessing it.

In view of these various considerations, I should be disposed to restrict the word pigment, in animals, to the substances responsible for their external coloration, including perhaps these same substances when they are encountered internally. Such substances are the only ones which ever truly function as coloring matters, that is to say as pigments, in the proper sense of the word, and even these probably have no such significance in a large proportion of cases. As to the "pigments" of our internal tissues and body fluids, and particularly the "respiratory pigments," let the verdict be "thumbs down."

That these suggestions of mine will have any effect upon current usage is too much to expect. Our mores, both as to the use of words and of pigments themselves, are little influenced by argument.

Let us, in conclusion, repeat the question: Why should biologists pay any particular attention to those objects or substances which chance to absorb and reflect light selectively? Why all this pother about pigment and coloration in animals? Our answers must be various. Some of them are rather obvious.

For one thing, colors and color patterns are frequently among the most conspicuous visible characteristics of animals. They are often the chief differential characters by which we distinguish one species from another.

Then, too, colored substances are much more readily perceived and recognized than colorless ones, and their spectral absorption bands figure prominently in their identification. These circumstances doubtless account in part for the attraction which the animal and plant "pigments" have for the biochemist.

Again, the colors of many animals bear very obvious relations to particular features of their environment. In some cases, colors are such as to render the animals extraordinarily well concealed in their more usual habitats; in other cases, we have the opposite condition of a high degree of conspicuousness, and again we have the well-known correlations between pigmentation and climatic factors. We still await adequate explanations of most of these phenomena.

Finally, we must recognize an element in our interest which is not scientific at all, though I half suspect that it is the most potent one for many of us. I refer to the esthetic appeal. A world without color would be a drab affair in more senses than one. Personally, I doubt whether I should be studying fishes, if they all looked like the pickled ones in our museum jars. Few of us have probably lost our childish preference for colored objects. It is my guess that even the concern of our physiologists over the bile and urinary "pigments" is an unconscious manifestation of this same infantile trait.

However that may be, color has figured importantly in nearly every branch of biology: in biochemistry, physiology, pathology, histology, taxonomy and genetics, both of animals and plants; as well as in psychology, both human and comparative. From whatever direction we approach the study of life, we can not escape the phenomena of color.

ISOSTASY

By Dr. WILLIAM BOWIE
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Isostasy, which has taken a rather prominent part in earth studies during the past few decades, has been much abused by both its friends and its enemies. Some of its most ardent admirers are inclined to think that it is a cure-all for every ill that afflicts Mother Earth. The acceptance of isostasy has been retarded much more by the inconsiderate stand of some of its friends than by the adverse criticisms of its opponents. There is a middle ground that we should take. There is no question but that isostasy in its general aspects, at least, is true, but there is much to be learned regarding details.

In future isostatic investigations and studies of the part that their results are to play in the general sciences of geophysics and geology, we must not depend upon the geodesist and the seismologist only, but also upon the geologist, the physicist, the chemist and the mathematician. The problems connected with isostasy and the application of the results of isostatic investigations to other branches of science are complicated. They require the combined thought and action of many groups of research workers.

The time has come for an attack on the problems of geophysics and geology with the earth treated as a unit. If we should solve some of the world-wide problems, then we could better understand the problems that are of a local character.

Isostasy is a most logical idea. According to it, the earth, approximately 8,000 miles in diameter, has an outer layer of moderate thickness, called the crust, that may be likened to a continuous strong blanket. A number of investigators, using different sets of data and several hypotheses, have derived thicknesses of the crust which lie between 40 and 125 kilometers. With more abundant geodetic data, more accurate values of the crustal thickness can be derived. It will probably be found eventually to lie somewhere between 40 and 80 miles.

The isostatic condition requires that the outer shell have residual rigidity and that sub-crustal matter have little or no residual rigidity to forces that act through geological time, say for hundreds, thousands or millions of years. It is not conceivable that with every shift of load on the earth's surface, no matter how small the load, there should be a corresponding sinking or elevation of the crust. The maximum load that the earth's crust can maintain without yielding is not known, but the gravity data that we now have indicate rather clearly that rock masses as great as a thousand feet in thickness extending over a wide extent of the earth's surface can not be supported for any great length of time.

It is reasonably certain that sediments deposited in shoal water can not alone greatly depress the crust. According to good geological evidence, sedimentary beds of 20, 30 or even more thousands of feet occur, and these sediments were deposited in shallow water. There must be an independent depression of the earth's surface to permit the accumulation of such thick beds. It is possible that these sedimentary areas were previously occupied by mountains or plateaus and that the change in temperature and

density of the crustal material resulting from erosion and maintenance of the isostatic balance may have caused the independent sinking.

The data, by means of which isostasy has been tested, consist of values of gravity and deflections of the vertical. For many parts of the earth the geodetic stations are widely separated. It is most desirable for the test of isostasy that intensive geodetic surveys be made over the whole surface of the earth, including the oceans. It is only by having large quantities of well-distributed data that we shall be able to solve the problem as to what degree isostasy is true for each limited portion of the crust.

The geodesists were forced to consider isostasy in carrying on their operations involving the derivation of a gravity formula, the determination of the figure of the earth and the computation and adjustment of arcs of triangulation. By using the idea of isostasy they have reconciled to a remarkable degree the observed and theoretical geodetic values.

One hears often, in isostatic literature, of gravity anomalies. An anomaly is merely the difference between the theoretical and observed values of gravity. An anomaly of one milligal, one millionth of gravity, is equivalent to the attraction of a layer of rock 30 feet in thickness and with the average density of surface rock. It is rather remarkable that isostatic anomalies as great as one hundred milligals are very rare. Such an anomaly would be the equivalent of an excess or a deficiency of three thousand feet of rock. We have many mountain and plateau areas that have far greater elevations than 3,000 feet and therefore we seem to be justified in concluding that even locally the earth's crust does not support extra loads, negative or positive, equivalent to 3,000 feet of rock with moderately extended horizontal dimensions. It has been found to be true, so far as tests can be made, that an isostatic anomaly as great as a hundred milligals is due largely to local causes. At stations that are not far distant from one having a very large anomaly, the anomalies in general are very much smaller.

Since isostasy is true in its general aspects, mountain systems and plateaus can not be extra loads, and therefore since those areas were at some time in the geological past below sea level receiving sediments from adjacent land areas, we must conclude that those areas have been pushed up. Whether the uplift was caused by horizontal or vertical forces is a major problem of the earth sciences.

Isostasy gives us a very good explanation as to why a mountain system exists for a great time in spite of enormous amounts of erosion. As material is moved from the surface, the isostatic balance is restored. If the difference in density of the surface and the subcrustal material is 10 per cent., the mountain will become lowered only 10 per cent. as much as the thickness of the material removed by erosion. Geologists have at times wondered how great beds of sediments could have come from previously existing mountains that must have occupied very limited horizontal spaces. It is seen from the above reasoning that the eroded mass may be five to ten times as great as that which was at any one time above sea level in the mountain mass.

There are two conceptions of isostasy, one by Pratt and the other by Airy. According to the former, changes in the elevation of the earth's surface are due to changes of density. According to the latter, the changes in elevation are due to a thickening or thinning of the crust caused by the action of horizontal forces. We do not now know which of these ideas is the correct one. Perhaps each of them

plays a part. It may be that the solution of this problem must be based upon a consideration of physics, chemistry and mechanics as they may affect the earth's materials. The geodetic data alone have been employed in the testing of the Airy and Pratt hypotheses, but it seems to me that we must bring other factors into the picture. However, it is possible, I believe, if we have much geodetic data in each of many mountain areas, to arrive at a fair conclusion as to whether the Airy or the Pratt hypothesis is the correct one. If Airy's idea is true, then under the highest mountains one would expect to find the greatest thickness of the crust. If Pratt's idea is correct, the depth of the crust should be nearly the same throughout.

Not only have we used the gravity anomalies to test the Pratt and Airy hypotheses, but we have assumed in many cases that the anomalies indicate exactly the extent to which the earth's crust may deviate from the isostatic condition. I think this view is erroneous. Instead, it is better to assume that a large isostatic anomaly at a gravity station may be due in large part to the presence of masses of abnormally light or heavy material close to the earth's surface and close horizontally to the station. This is notably true, for example, in the case of the isostatic gravity anomaly, nearly one hundred milligals, at Seattle, in the trough extending along the eastern margin of Puget Sound, in the state of Washington. At a station only 20 miles to the northwestward of Seattle, the gravity anomaly is very close to zero. Except for one station to the northward the other stations near Seattle do not have anomalies that approach 100. This indicates that the Seattle anomaly is caused by a local abnormal distribution of densities. If it were otherwise or if that anomaly were due to lack of isostatic balance under Seattle, the surrounding stations would likewise have very large anomalies.

In recent years the seismologists have been making notable progress in earth studies along their lines of research. They have found that records of waves from nearby earthquakes (less than 200 miles away) can be explained only on the assumption that some of the waves instead of following direct paths are reflected or refracted at surfaces of discontinuity whose depths can be determined. These surfaces separate the crust into layers of moderate thicknesses. The existence of the surfaces of discontinuity must be due to differences in the physical characteristics of the layers involved. But this does not mean, in my judgment, that the depths found for the outer layers of the earth's crust by seismological investigations limit the thickness of the so-called isostatic layer. I can imagine rocks of different kinds existing in distinct layers with each one of the layers undergoing changes in density, due to changes in heat and pressure, that would tend to balance the load of topography.

Many geologists are inclined to favor a very thin crust, but since there have been great changes in portions of the earth's surface during geological time, it would seem to be rather difficult to explain how these changes could have taken place with a thin crust. If changes of density cause changes of elevation of the surface, then the changes in density in many instances would have to be very great for the thin crust. If, on the other hand, the changes in elevations have been caused by world-wide horizontal thrusts, then we have the difficulty of explaining how a very thin crust can carry great forces through long distances and push up mountains and plateaus. I am inclined to think that the solution of many problems of geology and geophysics will be made easier if the

crust is assumed to have moderate thickness, say of the order of 60 miles.

If isostasy is true, then it would seem that the adjustments that maintain equilibrium must involve the horizontal movement of material below the crust. Erosion causes certain portions of the earth to be lightened and others to be weighted. The tendency will then be for subcrustal material to move from the sedimentary areas toward the erosion ones, but the stress differences will be in the opposite direction, or from the higher to the lower areas, until the depth of compensation, the lower limit of the crust, is approached. If this condition is true, then the isostatic subcrustal adjustment probably can not cause distortions such as folding and over-thrusting in the outer strata of the crust that lie over the large areas between the erosion and sedimentary zones.

Volcanology is a very important subject to be considered in isostatic investigations. There are outpourings of lava through fissures and the building up of great single mountains by volcanic action. Are these outpourings extra loads added to a block of the earth's crust? The answer to this question will depend upon the zones from which the volcanic material emanates. I believe the best opinion to-day is that volcanic matter does not come from subcrustal space but from within the crust itself. If this is true, the outpourings are extra loads on the earth's surface, but not extra mass added to the block of the crust beneath. The pressure exerted at the depth of compensation under an area in which there has been volcanic activity should be the same after as before it occurred.

As a result of erosion and sedimentation, changes of temperature of substantial amounts must take place in crustal material. The crust under areas of sedimentation is pressed down into hotter zones and under areas of erosion it moves upward by isostatic adjustment to colder zones. Eventually the isogeotherms resume their normal positions or depths and in consequence the crust is made hotter or cooler. The changes in temperature should cause changes of physical or chemical states of the crustal matter and result in changes in density. It is possible that the uplift of areas to form plateaus and mountains and the depression of other areas to form troughs may be due to changes in density resulting from changes in temperature.

It is important that an isostatic adjustment be made of all geodetic data in the form of deflections of the vertical and values of gravity. Methods have been developed that can be readily used. After the reductions have been made on one system, factors can be used for computing the effect of the compensation on other systems. Necessarily in making the isostatic reductions one should have a knowledge of the topography. It is only where there are topographic maps that indicate by contours the masses above sea level and charts that show deficiency of mass in ocean waters, that the isostatic reduction can be made with exactness. When the stations are on extended plateaus accurate topographic maps are not so necessary, since for such areas the effect of compensation is nearly the same as that of the topography, regardless of the assumed thickness of crustal material.

In our efforts to explain what has caused horizontal and vertical movements of crustal matter we must not do violence to fundamental principles of mechanics. It is not logical to assume that great and world-wide horizontal forces have been active without having a logical explanation of the origin of those forces. It is reasonably certain that thin strata can not be pushed uphill against gravity and against shearing and frictional resistance, or at least that such

a movement can not be great. Overthrusts of thin beds of strata do not mean that the whole crust of the earth has been involved. Even the overthrusts of strata of a mile or more in thickness, for great distances, present very difficult problems to explain. What is the cause of a comparatively small amount of strata moving great distances? Is it not possible that much that is called overthrusting is really underthrusting with the strata involved moving down slopes under the influence of gravity? It is my belief that we shall eventually reach the conclusion that the predominant forces are vertically-acting ones and that horizontal movements of strata are incident to the vertical movements.

According to the best geological evidence available there are few or no indications of horizontal movement in extended platèau areas. Therefore, it would seem to be logical to conclude that the cause of the elevation of the plateau surface is a change of density rather than the action of horizontal forces. Is the uplift of a mountain system entirely different from that of a plateau?

The isostatic studies are of great interest in the realm of pure science, but they have a practical value. Isostatic reductions are now being made by some petroleum companies searching for oil. It is probable that gravity and deflection of the vertical data, when isostatically reduced, help to discover oil, ores and, what is of great importance, undergroundwaters. The governments of the world and many private companies can well afford to help finance the prosecution of these lines of investigation. I believe that by such work great economies can be made in efforts to discover and utilize certain natural resources. It is hoped that private agencies conducting geodetic and geophysical surveys and isostatic investigations will make their data available to the scientific public after the information has served the special purposes for which it was secured.

THE DIESEL ENGINE AND ITS POSSIBILITIES

By SUMNER B. ELY
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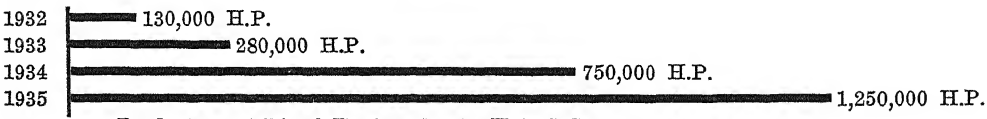
At the present time the public is Diesel-minded. A year or more ago stream-lining absorbed the public interest; and before that, at various times, radio, free-wheeling and other engineering ideas and novelties. Public opinion is not always logical or sensible over such matters. For example, at one time enthusiasm was so great that everything possible must be stream-lined. It became a veritable craze, and absurd advertisements appeared, such as "stream-lined roller skates," "stream-lined shoe brushes," etc. As a matter of fact, an automobile must travel at least fifty-five miles an hour before any appreciable saving will result from stream-lining.

To-day much the same thing is happening with the Diesel engine. We hear that we are now entering the "Diesel age," and we read in the papers that we are to ride to prosperity on the stalwart cylinders of the Diesel engine. However much this may be exaggerated, there is some very good background for public interest, as will be seen by a glance at the diagram of horse power of Diesel engines produced. The growth of the Diesel industry is indeed spectacular, and particularly in view of the fact that it occurred during depression years. This growth, among other things, such as the wide publicity given the successful innovation of the stream-lined Diesel-electric trains, has fired the public imagination, and it is no wonder that the Diesel industry has been heralded to miraculously pull us out of the depression.

Young men trying to earn a living have naturally turned to this supposedly new field, and as a consequence we find a large number of Diesel schools which have sprung up over the country. These schools are generally of a "practical" nature, where a small amount of theory is given with opportunities to observe an engine in operation or even to dismantle and assemble Diesel engines. The criticism advanced against them is that they not only promise to turn out an expert in a very short time, but assure any one who will take their course a certainty of immediate employment. As a matter of fact, there is little demand for Diesel mechanics and service men in the Pittsburgh district at the present time.

However, while at present the demand may be small, it is well to remember that in the last two or three years, several thousand busses in London have been changed from gasoline to Diesels, and many men have been needed. In our own country Diesel busses are being used more and more on our through routes.



Production of Diesel Engines in the United States
An increase of nearly 1000% in three years.

Some of our colleges and technical schools have tried to help out by popular evening courses, but adequate equipment in almost every case has been lacking; so too with high-grade technical education. While the fundamental principles are already included or can be included in existing courses, good examples of Diesel engines are needed in laboratories or

elsewhere. There are in the United States few colleges with suitable equipment to offer graduate courses in Diesel engineering. This information is the result of a recent questionnaire.

As almost every one knows, the gasoline engine used to-day in our automobiles consists of a cylinder, having in it a piston which is driven by an explosion of gasoline vapor. The reciprocating motion of the piston, through a crank, connecting rod and gears, is turned into circular motion at the wheel of the automobile.

To obtain an explosion (and explosion is nothing but very rapid burning), there must be a mixture of air and gasoline vapor, and in the proper proportion. The carburetor accomplishes this mixing by automizing liquid gasoline and metering the amount of air supplied. However, the carburetor can not properly atomize a heavy liquid. It must be supplied with an easily vaporized liquid fuel, such as gasoline, which has been derived from crude petroleum.

The first indictment against the present-day automobile, therefore, is that it can not utilize heavy oil fuels, which are comparatively cheap now.

In the early days of the internal combustion engine, it was discovered that an explosive mixture must be put under pressure before it is ignited; otherwise, instead of a quick, sharp explosion producing a high pressure, a long, slow burning with very little pressure results. Compression of the charge before explosion is absolutely necessary for the proper working of the engine. This is obtained in most of our automobiles by letting the piston fill the cylinder on its outward stroke, drawing in the mixture from the carburetor; the valve then closes so the mixture can not escape, and on the return stroke of the piston, it is compressed into a small space left in the end of the cylinder. The smaller this space, the higher will be the compression, which is commonly around 100 pounds to the square inch. The compressed mixture is now ignited by a spark plug, and the resulting explosion drives the piston on its outward stroke again, but this time developing power.

It is a well-known fact that the higher the compression before ignition, the greater is the efficiency of the motor; and the aim of the engineer is to increase the compression as much as possible. But here he soon reaches a limit. Any compressible substance, such as air or gasoline vapor, when compressed becomes warm; and the harder it is compressed, the hotter it gets. We all know how small hand air pumps get warm, and in large air compressors it is necessary to surround the cylinder with cooling water to prevent overheating and burning of the lubricating oil.

And so with the gasoline-vapor-air mixture; if compressed too much, it will become so hot as to explode spontaneously, without any spark whatsoever. This, of course, must not happen, as the time of the explosion must be controlled to prevent backfire and detonation. Each fuel has its own auto-ignition point. No-knock gasoline will stand higher compression than ordinary gasoline.

We may then make a second indictment against the present gasoline motor, *viz.*, the compression pressure and consequently the efficiency are limited.

About 1890 an engineer named Rudolph Diesel took out some German patents which were ultimately tried and worked out with the assistance of the German firms of Krupp and M.A.N. Diesel's idea was very simple, *viz.*, to do away with a carburetor and during the forward piston stroke to draw into the cylinder pure air only. On the return stroke this air was very highly compressed to some 500 or 600 pounds per square inch, which would bring it to a red-hot heat. Unlike the gasoline motor, no auto-ignition could take place, as pure air alone can not explode or burn. Into

this small volume of red-hot air, caught at the end of the stroke, liquid fuel was forced by means of an injection pump. The fuel of course would immediately burn and drive the piston forward again on its working stroke.

Here, then, is an engine which is simplified by having neither carburetor nor spark plug, although a somewhat complicated injection system has been added. Furthermore, it possesses two great advantages: (1) The ability to use cheap, heavy fuel oil; (2) due to the high compression, it has the highest known thermal efficiency.

The Diesel engine, as built to-day for equal powers, will use only about one half the quantity of fuel required by a gasoline motor; and in addition will use a much cheaper grade of fuel. The objection is often raised that if in the future the demand for Diesel fuel oil greatly increases, probably the lawgivers of this country will see fit to tax it as heavily as gasoline is taxed to-day. But even then there would still be a saving of one half the amount used. It has been estimated that in the Pittsburgh district the Diesel engine to-day could afford to pay for its fuel oil four times its present price and still produce power as cheaply as a gasoline engine. Furthermore, while the tax on fuel oil in the future may be increased, there will be great pressure brought to bear on the part of the oil companies to keep it down. The great bulk of fuel oil produced is used for other purposes than generating power in oil engines, and if its price becomes too high, these users will go to coal or other fuel, and the oil companies will find themselves left with a very restricted market.

To offset this great saving in fuel, however, the Diesel has a higher first cost and is heavier than the gasoline engine. It was stated above that the Diesel cylinder compression pressure was as high as 500 or 600 pounds per square inch; and after the oil is injected its combustion may raise it to 800 or 900 pounds or more. In the gasoline engine, on the other hand, the maximum pressure after explosion will seldom exceed 400 or 500 pounds per square inch. The Diesel must have thicker cylinders and stronger parts to resist the greater pressure and is consequently heavier and more costly. To express this in another way: due to the high compression and long expansion, to get the same *average* pressure per square inch on the piston throughout its working stroke, the *maximum* pressure is greater in the Diesel.

In the last analysis the Diesel will succeed or fail on its commercial efficiency. The cost of generating power is not a matter of thermal efficiency alone. We must take into account the interest on the investment, the cost of repairs, maintenance, wear and tear, length of service, etc., and this can only be determined by operation over a period of years. The Diesel engine has now been in operation for some twenty-five years and has demonstrated its worth. It does not seem to be generally known, but the fact is that to-day more than 50 per cent. of our shipping is equipped with Diesel engines. We perhaps think that this is so because the internal combustion engine does away with the inconvenience of a boiler; but records show that medium-speed ships that are constantly in service are equipped with Diesel engines, while those remaining in port for long periods have cheaper steam installations. In other words, where a great deal of fuel is to be used, it pays to make the larger investment and use the better saving equipment—a matter of dollars and cents.

In Europe, where fuel is expensive, we find many more Diesel engines than in America, where fuel is cheaper. The registration in Germany alone for 1935 was over 30,000 Diesel trucks, busses and automobiles, and it is estimated that the Diesel engine manufacturers of Europe together turn out 4,000 trucks and busses

monthly. To this must be added the Diesels installed in stationary service.

And in the United States we have already some fifty well-established Diesel engine manufacturers. They have stationary Diesels of moderate capacity in all kinds of service; lighting plants, pumping plants, ice plants, cotton mills, flour mills and in all sorts of industrial work. There is a growing demand for them in large office and hotel buildings. In many cases where steam power is already installed and the exhaust used for heating the building in winter, Diesels have been added, not only to increase the power of the plant, but to save the expense of operating the steam plant in summer. For example, the Hotel New Yorker has lately added 750 Diesel H.P., and 525 H.P. is installed in the Singer Tower, New York City.

The great impetus given the Diesel in the last few years has come about largely by improving the method of injection. The older Diesels injected the fuel oil by means of an air spray, in order to help combustion and regulation. This meant outside additional pumps and auxiliary apparatus. The Diesels built to-day are self-contained and the fuel oil is injected "solid" without air spray. This improvement has been accomplished by proper injection atomizing nozzles and pumps and by properly shaped combustion chambers, and has greatly simplified the engine.

Diesel installations are scattered widely throughout the United States; the demand for them of course varies in different localities, depending to a great extent on the cost of fuel in that locality. As a consequence, in the Pittsburgh district, where coal fuel is comparatively cheap, we find few installations; although there are a number of Diesel tractors and power shovels working around Pittsburgh and several river boats have Diesel engines. A number of large Diesel manufacturers have already established offices in Pittsburgh, and must believe there is a good Diesel field here, in spite of low coal fuel prices.

Regarding the application of the Diesel to automobiles and airplanes, the chief requisite is light weight. The power developed by an engine is a function of its speed. Consider an engine developing a certain horse power at a certain number of revolutions per minute. Using the same amount of fuel per revolution, if we can double the revolutions, the engine would use twice the total fuel and develop approximately twice the horse power; not exactly twice, as friction would modify it. However, the higher the speed of an engine, the more horse power is developed for the same weight, within limits.

The gasoline engine has the advantage of speed over the Diesel. A Diesel cylinder of the same power must be thicker to resist the higher pressures, and its piston and moving parts must be heavier. These reciprocating parts must stop and start at the end of each stroke. A gasoline automobile engine will run 3,500 or more revolutions per minute, which means starting and stopping them 7,000 or more times in a minute. The weight of reciprocating parts at high speeds is very important, for the engine may not stand up in service under the severe stresses they produce. Diesels do not generally exceed 1,000 or 1,500 revolutions per minute. A few have been built and operated at higher speeds, but they are more or less experimental and not tried out by much length of service.

As stated above, for equal powers, or equal size cylinders (same M.E.P. and same R.P.M.) the Diesel is heavier than the gasoline engine. But further, if the gasoline piston runs faster, its cylinder can be smaller and still produce the same power. Therefore, the gasoline engine has the additional advantage of smaller size per horse power due to its greater speed, which reduces the weight comparison still further.

All this means that the Diesel engine, if applied to an automobile, must run more slowly and therefore be larger and cost more than the gasoline motor. Of course the saving in fuel under some conditions may more than offset the additional expense; and in Europe we find quite a number of automobiles with Diesel engines. There are no Diesel-engined automobiles in the United States, except possibly an experimental one here or there. Should we start to apply Diesels it would mean larger, heavier and more expensive cars; and under present fuel conditions here, it seems hard to believe that the public would pay the increase.

While we may not see Diesels applied to passenger cars in this country, it looks as if the Diesel was likely to take over the whole field of trucks, busses, tractors and transportation machinery where slower engines are used, and fuel cost is an important consideration. We find great numbers of these machines now in the United States, particularly in the West, working on farms, earth stripping, road making, in logging camps, etc. The Caterpillar Tractor Company on January 1, 1935, made the statement that they had 28,352 tractors in service.

Regarding the airplane, its propeller, to be efficient, should run around 1,800 or 1,900 revolutions per minute. Diesels have been made to run at such speeds, and some airplanes have been equipped with them; but as already stated, for equal power developed, the gasoline engine is lighter; and as weight is such an important consideration, the Diesel is not likely to become popular with airplane builders. Furthermore, in order to reduce still more the weight of the airplane, we have lately seen high-speed gasoline engines used. Instead of directly connecting the engine to the propeller shaft, gearing has been used, allowing the engine to run at a greater speed and thus to decrease its weight for the same power.

When we come to consider very large installations, such as great central electric generating stations and our very large ocean ships, here again the Diesel is at a very distinct disadvantage. There is a limit to the size of a Diesel cylinder. If the diameter exceeds 35 or 40 inches, it is very difficult, with the high temperatures which constantly occur, to prevent the cylinder heads and bodies from cracking. And even if a successful cylinder of very large diameter could be built, it would be too heavy and cumbersome for practical service. The consequence is that large powers can be obtained only by using a great many cylinders. This involves great expense, immense weight and a very large space in which to house them. This is also true of steam engines.

Compare this with the present-day steam turbine, which can be built for enormous horse powers so compactly as to be easily operated and manipulated, and of less first cost and much less weight. In the turbine immense volumes of steam blow through a long cylinder in which is a rotating piece only, with no reciprocating parts to limit the volume of steam taken in. Steam turbine units can be built to generate 50,000, 60,000 and more horse power; whereas a ship such as the *Saturnia,* having 20,000 horse power of Diesel engines, is a very large installation indeed. There are sixteen cylinders, 36″ diameter × 42″ stroke, and the reciprocating parts of each cylinder weigh something like four tons. Special tools and devices are necessary to get at the inside of the cylinders to examine and repair them. Of late years, too, the thermal efficiency of the steam turbine has been improved; and while not as high as that of the Diesel engine, we may be very sure that steam will still be used to produce our great powers.

THE UNITED STATES COAST AND GEODETIC SURVEY AND THE PROPERTY OWNER

By PHILIP KISSAM

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THE ownership of land is perhaps the most fundamental economic consideration. Through the ages, primitive tribes have fought for the possession of land or for the right to hunt and fish in certain areas. To-day nations contend with each other for control of the land. Under whatever political scheme a state is organized the dedication of certain parts of the land for ownership or for definite uses is preeminent in importance. The life blood of a democracy depends upon the right of the individual to own, under certain restrictions, a definite division or portion of the commonwealth. The very development of civilization is dependent upon the allocation of real property for designated uses either by individuals or the state. For this reason the position of land division lines or land boundaries is of singular importance.

It is unbelievable, but nevertheless the fact exists, that in the United States it is next to impossible to accurately determine the precise position of any land boundary. State lines are sometimes in doubt; the boundaries of public rights-of-way (highways and streets) are notoriously intangible; and the positions of private holdings which depend upon the actual location of streets and roads are seldom, if ever, positively determined. The average property owner, complacent in the false security that his fence lines mark the boundaries of his property or that his place of business is built on the city lot he has purchased, seldom gives serious thought to these conditions. A survey has been made, his property is carefully described in a recorded deed. Why should he go further to assure himself that no one can eject him from his holdings? But let us inquire a little further into the actual facts. How was this survey performed? Or, how was this careful description procured? How dependent are these locations of his fences or buildings on the judgment of the surveyor and how dependent on his skill?

Let us look for a moment at the sequence of events by which this particular parcel of land was determined upon. Original title must be acquired by force of arms. Through this means the land becomes the property of the king or state. By grant or sale the land is then divided among original proprietors. Mountain ranges, natural waterways, etc., mark the boundaries of these grants. Such land marks are excellent for great areas but are useless when later they must be used to delineate city lots. As further division of the land occurs, natural features soon become inadequate. Artificial markers, known to surveyors as monuments, are erected to preserve the location of boundary lines; trees are blazed, stones heaped up; stakes or irons are set to mark positions. From their very nature such marks are temporary. With the loss of these markers disputes have arisen which can never find satisfactory solution. The force of circumstances has thus developed the common law practice which gives title of land to any one who believes that he owns the land, has defended the land from encroachment and used the land unchallenged for a certain term of years. Fences of themselves

become actual markers of boundaries, even though they may be originally built in a wrong position. It would seem that such a provision would effectively stabilize actual holdings. On the contrary, it usually introduces many complexities for the surveyor to solve. A fence may for convenience be built at one side of the line by agreement between both owners. There is always the possibility that a land mark may have been secretly moved by an interested party. The accepted boundary may have been contended less than twenty years ago. A fence or party wall can never be accepted as a boundary without careful scrutiny.

Written descriptions of the property based on surveys are recorded in the effort to stabilize the positions of the boundaries. A purchaser together with the vendor may temporarily mark the boundaries of the purchase. A survey of these marks is made with a steel tape and a transit, and thus the length of the various sides and the angles of the corners determined. The next step is the one which introduces all the difficulties. The surveyor must write a description of this property based on his survey. He can perfectly describe a piece of land of the correct shape, but how can he describe where the land is? He uses points of reference, either tangible or intangible. Whatever land mark he may choose, the utility of it is slight, because without question it will be lost or destroyed. Frequently he places monuments or stones, or iron pipes at the various positions. If these marks are in a town or city, sidewalks are built over them, they are removed for street or private construction; if in the country, they are covered by vegetation—all in a surprisingly short time. Usually he references his work to public rights-of-way. The boundaries of the public rights-of-way are the most indefinite of all. Since they are exempt from the common law, mentioned before, no individual can acquire parts of public property by fencing them in or building on them and holding them unchallenged for a term of years. Thus the boundaries of public rights-of-way are seldom carefully watched, and their positions are lost more quickly than private holdings.

Let us consider the next step in the division of land. The location of some property may be such that it is more valuable for residence or business purposes than for farming or other utilization of this soil. The ownership of small lots by many persons is the natural step toward further development. In order to advantageously sell one lot it is clear to the owner that a complete plan should be made so that future streets can be placed in their proper positions by reserving areas for them. He employs an engineer to work out a proposed plan and to compute mathematically the sizes and shapes of the various lots from the dimensions given in the original deed. A purchase is made and marks must be placed in the ground showing the location of that particular lot. The surveyor employed searches in vain for the original boundaries of the tract. With what skill and judgment he can muster he determines the location of the public right-of-way and the exterior boundary lines, and measuring from these he stakes out the lot or perhaps several lots. His judgment is called upon because what marks he finds are not consistent. With the measurements between them as recorded in the deed he must decide whether the marks he finds are in fact markers of the property, and if so, whether they are in their original position, and with what accuracy the original survey was made. As the cost of a survey is the direct function of the accuracy and the original tract was worth comparatively little when the survey was made, chances are very good that inac-

curacies are prevalent. Other lots may have to be laid out later by another surveyor. He too has no points of reference and the work of the previous surveyor may be lost. He too must use his judgment, and the relative position of the lots which he lays out to the previous lots and to the public rights-of-way is necessarily at variance with the plan. A new street may be established, which again must be located by judgment introducing a third variable.

The writer does not wish to infer that conditions of this kind occur in well-operated real estate subdivisions, but the greater percentage of the land is divided piecemeal and at various times as the need for it makes it an advantage to the owner to sell small portions. Perhaps 95 per cent. of the real estate in the country has changed from the farm to city lot in this way, landmarks being continuously lost throughout the process. The result, of course, is confusion, arguments, lawsuits and damage to title.

Let us follow the history of this land a little further. After it has become a residential or a business section of a town and a piece of property is to change hands, a surveyor is asked again to show the location of a certain parcel. In spite of the very careful description of the parcel found in the deed, it is fatal for the new owner to build on property marked out in accordance with this description. The surveyor must make a careful study of all the lot locations in the area. He must find just what is called for in the deeds of the properties within the entire block in which the lot is located, and perhaps even further away. He must find by careful instrumental determination where the lots actually are located on the ground, which of course again is difficult, as many of the marks will have been obliterated. After some period of careful research he can mark the property again according to his judgment. When he measures his final location, he finds that it does not agree with the original deed. Had he made it agree, the property would overlap the adjoining property, as there may be perhaps not enough land existing to satisfy the deeds in the area; or he may have been forced to twist the lot or move it this way or that from its deed location in order to eliminate discrepancies. Theoretically he should inform the new buyer of the existing situation. He should report the divergence in shape, size and position of the lot as he has marked it, from the location according to the deed. When so informed, the buyer should request the seller to procure a court ruling defining the position of the proposed purchase. As the chief evidence in such a court procedure will be obtained from testimony of the surveyor, the decision of the court would probably follow the lines of the surveyor's decision. Also little value would accrue to the buyer from this action as findings of the court could be no more permanently marked than the findings of the surveyor, even though the court decree would temporarily clear the title for the purchaser.

The usual procedure is much more simple. The buyer is entirely uninterested in the findings of the surveyor, after the surveyor has staked out the lot. He accepts a deed from the vendor containing a description of property which the surveyor knows is not consistent with the actual property. Moreover, should the surveyor suggest that a new and correct description, based on his survey, be included in the deed in place of the old description, the vendor might seriously object. The vendor must guarantee the title, and he is advised that it is easier for him to defend the title of the property if it is sold by the same description as the one by which he acquired the property, even though he may be guarantee-

ing title to something which is non-existent. The new survey is therefore thrown into discard and the old erroneous description kept. It is hardly necessary to point out that not only are surveys needlessly complex and costly but that titles are damaged and lawsuits encouraged. What is the keynote of the difficulty? What is the origin of this continuous confusion? *It is the lack of permanent well-known indestructible points of reference.* From the above discussion it is evident that such permanent points are extremely difficult to attain. What answer can be given?

Let us suppose that monuments were carefully set throughout the city or area involved in positions where they are least liable to disturbance. Let us suppose, then, that the *relative* positions of these monuments are determined with precise surveys. It is obvious that should any of the monuments be lost they could be replaced by measurements from the others. The permanency of each would be increased by the existence of the others. It is easily understood that the complicated angles and distances ordinarily required to describe the relative positions of many such monuments might burden the records and cause confusion. For this reason the method would be enhanced by the establishment of a system of plane coordinates. A system of plane coordinates is nothing more than a mathematical method of laying a rectangular grid over the entire locality. The position of each monument could be determined by expressing its distance accurately from a given north and south line together with its distance from a given east and west line. If the lines of reference are chosen far enough west and south of the given area, it will only be necessary to state the number of feet the point lies east and north of these lines of reference, *i.e.*, to give the "x" and "y" coordinates of the point, in order to completely describe its position. No mathematical difficulty is encountered in this procedure, if the angles and distances have been measured. In fact the rectangular plane coordinate system is so mathematically simple and advantageous that the positions of the property corners themselves should be described in this manner, making only a very simple computation necessary to locate the property from *any* monuments in the neighborhood.

How much better it would be if such a coordinate system were extended over an entire state, with monuments distributed throughout and connected by accurate surveys. Every property could be located accurately from any monument, its position could never be lost, discussions could not arise, and every monument within the boundaries of the state could be reset, if necessary, by measurement from any other monument.

The foundation for such a plan was laid in 1807 with the establishment of the U. S. Coast and Geodetic Survey. At that time a small system of triangulation was established in the metropolitan area of New York City, extending over parts of Long Island and New Jersey. Since that time, the net of triangulation has been extended to reach the Pacific Coast and cover the United States from Canada to Mexico. Thus there now extends throughout the country a vast system of marked triangulation points, their relative positions determined by precise surveys. The precision and accuracy found in the work of the U. S. Coast and Geodetic Survey has become a byword among engineers. Let me illustrate how accurate and permanent the positions of these points really are. A triangulation point marked by an earthenware cone buried two feet below the ground surface was established in New Jersey in 1839 in the course of the work of some of the earlier triangulation. Vegetation soon covered the scar in the earth which marked its position, and had it been a

boundary marker it would never have been seen again. But it was a triangulation station and it became desirable to find it. There existed a triangulation marker thirty miles to the south, and another forty miles to the northeast both of which had been set during the survey of 1839. By various systems of triangulation connecting with the old work, the relative position of the lost point with respect to these two old markers was determined. A monument was set on the same hill as the lost station. (The old records carefully described the hill.) An arc of triangulation was run seventy miles across country, connecting this new monument with the known triangulation points. With the results of this survey it was possible to compute the relative positions of the old point and the new monument. An angle was turned, a short distance measured, and a hole dug, and there, firmly set in the earth in the position calculated, appeared the old earthenware cone, lost from the sight of man for over ninety-seven years.

The U. S. Coast and Geodetic Survey has established plane rectangular coordinate systems for every state. In large states like Texas and California, several zones of coordinates are necessary. It might be asked, how can a plane coordinate system be applied to the curved surface of the earth? By using accurate projections plane systems can be extended over considerable areas without introducing material inaccuracies. These inaccuracies or "scale corrections" are of such a minor nature that the usual accurate survey will not show the discrepancy. Where the coordinates of a property corner have been determined, every monument in the entire national system acts as a witness point for that property corner, and its position is determined forever.

There are now in progress through the initiative and encouragement of the U. S. Coast and Geodetic Survey, in fourteen states, emergency projects for the purpose of establishing many thousands of monuments conveniently located along highways and streets and connected by surveys with the triangulation points of the U. S. Coast and Geodetic Survey. The relative position of each of these monuments is determined and their plane coordinates computed. They are set in pairs over one thousand feet apart, so that direction, as well as position, can be obtained from them.

Such is the service of the U. S. Coast and Geodetic Survey to the property owner. Although only recently available, this service has already passed the experimental stage. Government lands deeded by the Tennessee Valley Authority are described by this method. New Jersey has passed a law making the system the legal base for describing property within this state. Already many blueprints and plans of engineering development show monuments with their New Jersey plane coordinates. Large corporations are seizing this opportunity of permanently marking their lands. In the state of Massachusetts the Land Court now uses no other system. Public land monuments in Iowa are being surveyed for their state coordinates, so that they never again can be lost. France, Germany and England have been using similar systems for many years.

It is a great achievement that, in spite of every discouragement, lack of public appreciation, meager appropriations and underpaid personnel, the U. S. Coast and Geodetic Survey has spread this great triangulation net over the entire country and developed for the country this scientific method of permanently marking land.

THE AGES OF THE STARS

By Dr. L. V. ROBINSON
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According to the theory of relativity the total energy content of any material body, such as the sun or any of the other stars more remote from the earth, is directly proportional to the mass. Expressed in a mathematical form, this relation is

$$E = mc^2$$

where E is the energy, m is the mass and c is the velocity of light. For convenience, it may be further assumed that E is in ergs, m in grams and c is in centimeters per second. In this case c has the value of $3 \cdot 10^{10}$ or 30,000,000,000.

The theory of relativity makes no attempt in any way to predict the transformation of mass into energy; but through the above equation it specifies, rather, how much a body has decreased in mass and in weight when its energy content has in any way been diminished. In other words, the theory has nothing to say as to whether or not all the predicted energy is available.

Energy may appear in many different forms; and in most of these, if not all, the sun and the stars abound in it. At the distance of the earth from the sun (93,000,000 miles), however, most of the solar energy is manifested in the form of heat. In fact, all the energy utilized in any way by man may be traced to this source. An acorn grows into a tree by making use of heat energy absorbed from the sun's rays. When wood is burned, this energy is liberated, and part of it may be transformed into mechanical energy, as in the case of the steam engine. Inasmuch as the potential energy contained in thunder-heads and rain-clouds originates from the sun's heat, expended in converting water into mist and vapor and in raising it to great heights above sea-level, the electrical energy derived from water-power likewise owes its origin to solar energy. Energy from the wind may also be traced to the same source. In fact, the civilization of man has advanced according to his ability to apprehend and to exploit energy gained from the sun, until now he not only reassembles that intercepted by the earth in his own era, but from the coal mines and oil wells he is tapping the supplies stored up by the sun in the earth's interior millions of years before he appeared upon the scene.

Since c^2 is so enormously large ($9 \cdot 10^{20}$ or 900,000,000,000,000,000,000), a very minute quantity of matter corresponds to exorbitant supplies of energy, provided of course these supplies can be tapped. The converse is the well-known fact that the gain in weight by heating a body, although a reality, is much too small to be detected by ordinary methods. The magnitude of these statements can best be appreciated from a few simple calculations. It can be shown that in one ounce of matter, in any form, there is ample energy to lift 943,000,000,000 tons a distance of one foot. If this energy could be extracted, it would suffice to run an engine of 108,700 horsepower for one year. It would raise the temperature of 108,000,000 tons of iron 100 degrees, Fahrenheit, or would be sufficient to give this huge mass of iron a speed of more than 500 miles per hour. The converse of each of these statements is also true. That is, 108,000,000 tons of iron, for example, would decrease in weight one ounce by cooling from 100° to 0°, Fahrenheit; and 108,000,000 tons of iron, for example, would gain one ounce in weight as measured by an ob-

server at rest if its speed could be raised to 500 miles per hour.

Since the earth began, about 2,000,000,000 years ago, the sun has been sending to it as much heat energy as could be supplied by engines of 1.5 horsepower placed on each square yard of the earth's surface. Whatever the source of all this energy, the sun has been losing 4,630,000 tons in weight every second of this long interval of the earth's existence. Yet, in nearly 2,000,000,000 years, it has lost only one pound out of every 7,500 pounds of its former weight. This means that the sun now weighs 2,188,000,000,000,000,000,000,000,000 tons and that in a little less than 2,000,000,000 years it has lost only 291,700,000,000,000,000,000,000 tons! In spite of this loss, the sun that is now supporting all forms of life on the earth is essentially the same sun, both in mass and in brightness, as the primordial earth beheld nearly 2,000,000,000 years ago.

It is quite impossible to imagine the magnitudes of the quantities represented by these numbers; and we are by no means consoled when we are asked by the modern astronomer to think of a star, such as S Doradus, giving out a half million times more heat and light than would the sun if placed at the same distance. This means that in weight, also, this star is decreasing one-half million times more rapidly than the sun; in other words, it loses in one second about 2,300,000,000,000 tons of light and heat. Bewildering though these figures may appear, they are none the less real. They have the support of actual measurements. Furthermore, there seems to be no escape from the conclusion that the sun—although approximately an average star—can at best afford only a very feeble comparison with some of the other far-away suns in actual brightness. In fact, in 1885 a star appeared in the constellation of Andromeda which was even more luminous than S Doradus and was proportionately more brilliant than the sun. Stars of this type, however, are abnormal; and their lives of lavish dissipation are short. They are apparently huge celestial conflagrations, and in most cases a few days suffice for them to adjust themselves to more moderate outputs of energy.

The materials of which the stars are built are much the same as those entering into the earth's constituency. In fact, man has not been able to find a single element in the stars with which he is not now familiar; and he is ever on the alert with the spectroscope examining stellar atmospheres to determine not only what elements are present but also how much of each element is to be found. With matter, however, the stars apparently are able to do at least one miracle not yet understood by man. Were man able to transform even one ounce of matter into energy, his power problems would be solved. The stars, on the other hand, evidently do this harmoniously without one iota of the intelligence of man. Man has been on the earth only about one million years, and in comparison with the earth and the stars he is yet an infant—perhaps too young to play with so much fire, for Mother Earth would not be a safe abode for one who could accomplish this feat of the stars.

Not only are the stars able to derive this huge output of energy from their interiors in a way not yet familiar to man, but they are also able to adjust the outward flow of energy so that their spans of life are much more uniform than the "three score and ten" proverbially allotted to man. This interpretation follows from the so-called mass-luminosity relation discovered by Sir Arthur Eddington. From this relation the mass of a star is known with some degree of precision once its intrinsic luminosity is known. More explicitly, the more luminous the star the more massive it is. In other words, the stars of great intrinsic brightness and great

mass in a given time interval radiate away into space a greater percentage of their masses than do the less massive ones; a star with ten times the mass of the sun will decrease to half its present mass in a much shorter time than will the sun, and similarly the sun will decrease in mass to one half its present value in a much shorter time than will a star having a mass one tenth that of the sun. Strictly speaking, the mass-luminosity relation is one between mass and the rate at which the mass is decreasing.

The mass-luminosity relation lends itself more readily to a mathematical analysis when given in the form,

$$m = 1.83e^{-0.17M} + 2.17e^{-0.56M} \qquad (1)$$

Here m is the mass, M is the "absolute magnitude" and a measure of the intrinsic luminosity, and e is the base of natural logarithms—about 2.718. This equation can make no claim to any higher degree of accuracy than the mass-luminosity relation itself, but within the limits between which masses and intrinsic luminosities of the stars are known the agreement is remarkably close.

The relation of intrinsic luminosity to mass is illustrated in Fig. 1, whence it is seen that the range in intrinsic brightness among the stars is very much wider than in mass. Although at its maximum S Andromedae, the bright nova which appeared in the nebula in 1885, was much more luminous than 100,000,000 suns such as ours, it is doubtful if its mass is as much as 50 times that of the sun; it is certainly less than the value computed by equation (1). Indeed, those stars which have masses as great as 100 times that of the sun seem to be relatively quite rare. Such may not be the case, however, for the stars of small mass. Very probably these are much more numerous than the observational evidence would indicate. According to the mass-luminosity relation, such stars are also

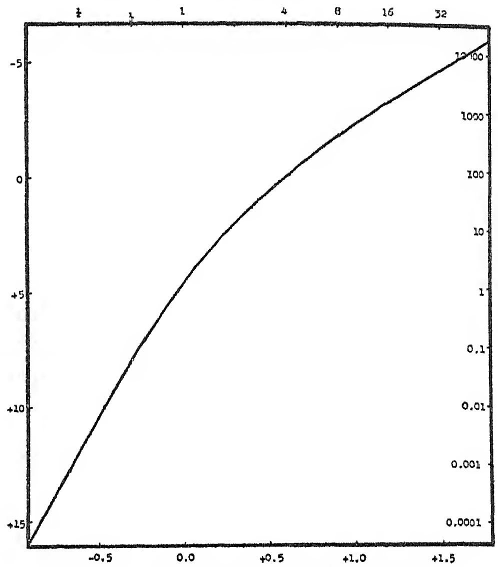


FIG. 1. THE MASS LUMINOSITY RELATION

THE SCALE OF THE ABSCISSAE IS A LOGARITHMIC ONE, VALUES OF LOG M BEING WRITTEN AT THE BOTTOM AND THOSE OF THE MASS M AT THE TOP OF THE FIGURE. ORDINATES AT THE LEFT HAVE THE SCALE OF ABSOLUTE MAGNITUDE, AND AT THE RIGHT ARE THOSE OF LUMINOSITY IN TERMS OF THE SUN'S LUMINOSITY. (DATA ARE FROM RUSSELL, DUGAN AND STEWART, *Astronomy*, VOL. 2, P. 691.)

of small intrinsic brightness and have little chance of being discovered. Although of all the fixed stars Proxima Centauri rivals α Centauri for the place of closest proximity to the earth, it is so feeble in intrinsic luminosity that it can not be seen without the use of the telescope; and ordinarily astronomers do not attempt to measure the distances and intrinsic luminosities of stars so faint unless evidence of close proximity is indicated by a relatively high proper motion with reference to the other stars. Yet one star, Ross 248, has been discovered which apparently gives less light than Proxima Centauri. No less than 30,000 stars such as Ross 248 would be required to give as much light as our own sun if both could be observed at equal

distances from the earth; but, according to the mass-luminosity relation, its mass should not be much less than $\frac{1}{9}$ that of the sun. In comparison with S Andromedae, therefore, the known range in intrinsic luminosity is approximately 3,000,000,000,000 times, while in mass the heaviest of the stars probably is not greatly in excess of 1,000 times that of the smallest. Stars very much less massive than $\frac{1}{9}$ that of the sun, if they exist, would be so feeble in light-giving power that their masses should remain appreciably constant almost indefinitely. Indeed, the following discussions seem to warrant the conclusion that from radiation alone the time interval required for a star to decrease from a value comparable to that of the sun to $\frac{1}{9}$ of that value is 25 times as long as is required to decrease from 100 times the mass of the sun to its present value.

If the changes in a star's mass are due only to losses in radiation, the time interval required for it to decrease from infinite mass to a mass m corresponding to an absolute magnitude of M is, in years,

$$T = 1.72 \cdot 10^{11} \int_m^\infty e^{0.921M} \partial m \qquad (2)$$

This equation follows from the relativity relation between mass and energy and from the fact that the luminosity L in the equation, $M = 4.85 - 2.5 \log L$, is the rate of change of the energy E with respect to time. Since the sun's luminosity is taken as unity, its absolute magnitude by the last equation is $M = +4.85$.

As applied to the older stars, the results which follow from equation (2) are little affected if the ideal condition of infinite mass is replaced by an assumption of an initial value of 100 times that of the sun, say. For stars having masses above this value, the radiation is almost explosive in character—that is, provided such stars conform to the mass-luminosity relation of equation (1). On the other hand, it has been suggested that the gravitational pull resulting from such a large mass might be so large as to offset the enormous pressure of the outgoing radiation and to prevent the escape of light, making them invisible.

From equations (1) and (2) it can now be shown that the time, in years, required for a star to decrease from an infinite mass to a mass m, corresponding to an absolute magnitude M, is

$$T = 7.125 \cdot 10^{10} \quad e^{0.751M} + 5.791 \cdot 10^{11} \quad e^{0.361M} \quad (3)$$

The ages of stars of different absolute magnitudes M and masses m computed by means of this equation are given in Table I, and the results are illustrated graphically in Figs. 2 and 3. Similar results have also been obtained by other investigators. As an upper limit to the age of the sun, a period of $6.13 \cdot 10^{12}$—or 6,130,000,000,000—years is found for the time required for it to shrink from an infinite mass to its present value. Had its initial mass been only 100 times its present value ($2.19 \cdot 10^{27}$ tons), the calculated age of the sun would be rather $6.08 \cdot 10^{12}$ years. In other words, its age has only been shortened by 51,500,000,000 years, which is the time required for a star to shrink from infinite mass to one of 100 times that of the sun, according to the calculations. Such a decrease in mass in so short a time as 51,500,000,000 years is, cosmically speaking, almost explosive in character. As opposed to the view that the very heavy stars might have a gravitational field so strong as to prevent the escape of matter (or of energy) moving with the velocity of light, it can be shown in passing that the mass of such a star should be about 480 times the radius, when the mass and the radius of the sun are taken as standards; and this fact fails to harmonize with observations. The ratio of mass to radius for the

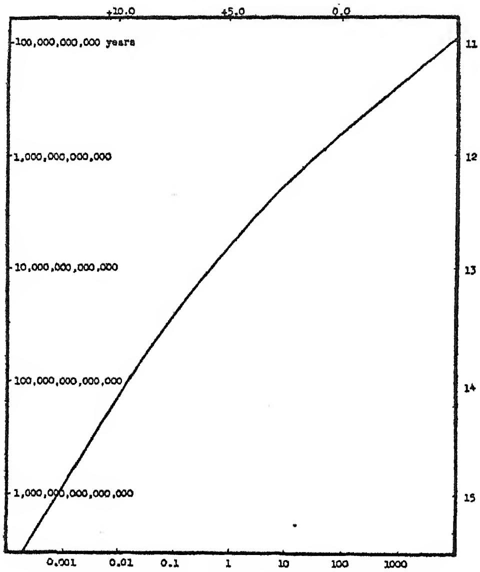


FIG. 2. THE AGES OF STARS OF DIFFERENT LUMINOSITIES

AT THE BOTTOM THE ABSCISSAE ARE INTRINSIC BRIGHTNESSES IN TERMS OF THE SUN'S BRIGHTNESS AND AT THE TOP ARE ABSOLUTE MAGNITUDES. THE ORDINATES AT THE LEFT ARE AGES IN YEARS AND AT THE RIGHT ARE LOGARITHMS OF THE AGES.

sun, for example, is unity; and among the other stars, this ratio decreases very rapidly with increasing masses. It is quite contrary to observation, therefore, to suppose so large a value of this ratio as 480 is to be found for very large masses.

The fact must not here be lost sight of, however, that mathematics is an ideal science, and only under ideal conditions does its language conform to the truth. It is not that figures are inherently subject to error but rather that in shaping them to the necessary conditions and assumptions peculiar to the problem they may be made so by the imperfections of the human technique. Some of the assumptions made here, possibly subject to error, are: (1) the theory of relativity is applicable. (2) There are no exceptions in any stage of stellar evolution to the mass-luminosity relation of equation (1). (3) The initial mass of a star is infinite. (4) No change in mass is admitted except through losses in radiation. (5) Astronomically speaking, there is no end to the radiation of mass. (6) No allowance is made for the possibility of a single star breaking up into two or more components or for other possible discontinuities in the equations.

As to the first of these assumptions, the only possibility of error seems to consist in denying the whole theory of relativity, and modern science will not afford such a step at present. Whatever the source of all the energy which the stars pour out, the theory maintains that the expenditure of energy must always be attended by a corresponding decrease in mass. Light, which is a form of energy exerting a pressure—although very slight—upon all surfaces on which it impinges, must also have mass and weight according to the theory; and when light is emitted, weight is therefore lost by the source.

Although it is tacitly assumed that the relation between mass and luminosity is accurately specified by equation (1), the evidence seems to be against so strict a correlation as a one-to-one correspondence. For example, the most accurate measurements of the absolute magnitude of the sun indicate a value $M = +4.85$ for which equation (1) predicts a mass, $m = 0.95$, instead of the standard value of unity. It is quite probable, however, that at least a part of the divergencies from the mass-luminosity relation is due to inaccuracies of measurements; and in any case, admitting some small deviations, the results to which equation (1) leads seem to be good approximations. At least this is true over the known range of star masses, which extends from about one fifth to a few hundred times the sun's mass; and it is only to this range that the mass-luminosity relation is applicable with any confidence. On

the other hand, stars with gravitational fields sufficiently strong as to prevent the escape of radiation—if indeed such should exist—are also outside the range of the present discussion, forasmuch as they do not conform to the predictions of equation (1).

It has already been shown that the assumption of an initial mass of 100 times the sun's mass subtracts only about 51,500,000,000 years from the figures given in Table I, which has been calculated with the assumption of an infinite mass initially; and for the older stars so short a period as 51,500,000,000 years is quite negligible, astronomically speaking. It is better perhaps to define here the "age of a star" as the time required to decrease continuously from an initial mass of infinity to a present value, without any gain or loss to outside sources, except through radiation. Such a definition is found also to satisfy other objectionable features which follow. As will be seen later, the fact that the very bright (and therefore the very massive) stars are quite infrequent is itself sufficient evidence that the time interval represented by the earlier stages of evolution in a star's life must be relatively quite short. What precedes the stellar stage astronomers are yet not unanimously agreed; perhaps the best tentative suggestion is that the nebulous wisps shown in Fig. 4 eventually condense into one or more stars. At least, such nebulosities, which for the most part are found in or near the Milky Way, are as yet in a state quite rarefied and shine only by the light from other stars in their neighborhood — conditions which presumably might precede a stellar state.

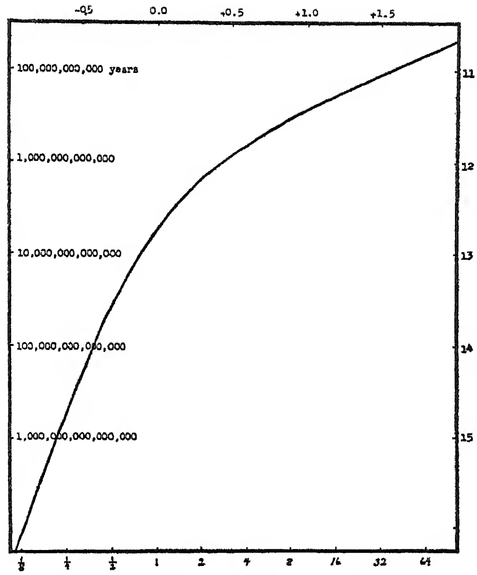


FIG. 3. THE AGES OF STARS OF DIFFERENT MASSES

AT THE BOTTOM THE ABSCISSAE ARE MASSES IN TERMS OF THE SUN'S MASS AND AT THE TOP ARE LOGARITHMS OF THE MASS. THE ORDINATES AT THE LEFT ARE THE AGES IN YEARS AND AT THE RIGHT ARE THE CORRESPONDING LOGARITHMS OF THE AGES.

The fourth of the above assumptions, the supposition that a star does not

TABLE I

M	L	m mass	log m	T Age in years	log T
− 5	 8710	40.0	+1.60	96,900,000,000	10.986
− 4	 3470	24.0	+1.38	140,000,000,000	11.147
− 3	 1380	14.7	+1.17	204,000,000,000	11.309
− 2	 550	9.2	+0.96	297,000,000,000	11.473
− 1	 219	6.0	+0.78	437,000,000,000	11.641
0	...... 87.1	4.0	+0.60	650,000,000,000	11.813
+ 1	...... 34.7	2.8	+0.44	982,000,000,000	11.992
+ 2	...... 13.8	2.0	+0.30	1,510,000,000,000	12.180
+ 3	...... 5.5	1.5	+0.18	2,390,000,000,000	12.378
+ 4	...... 2.2	1.2	+0.06	3,890,000,000,000	12.590
+ 5	...... 0.87	0.91	−0.04	6,560,000,000,000	12.817
+ 6	...... 0.35	0.74	−0.13	11,500,000,000,000	13.061
+ 7	...... 0.14	0.60	−0.22	20,900,000,000,000	13.320
+ 8	...... 0.055	0.49	−0.31	39,400,000,000,000	13.595
+ 9	...... 0.022	0.41	−0.39	76,300,000,000,000	13.883
+10.0	...... 0.0087	0.34	−0.47	152,000,000,000,000	14.180
+12.5	...... 0.00087	0.22	−0.66	903,000,000,000,000	14.956
+15.0	...... 0.000087	0.14	−0.84	5,690,000,000,000,000	15.755

suffer any change in mass except by radiation, very probably is not substantiated by the facts. Although most meteors in passing through the upper layers of the earth's atmosphere apparently are burned up, their ashes undoubtedly fall to the earth; and the mass of the earth, from this source, must be slowly increasing. This increase of mass would be much more pronounced in the case of the sun and the stars, for the reason that their gravitational pull on outside bodies (such as meteors) would be much stronger than that of the earth, since their masses are larger than that of the earth. On the other hand, the sun, and probably likewise the stars, seems to be slowly losing mass in the form of atoms and electrons, thus probably accounting for the aurora borealis, or the "northern lights." Expanding shells of nebulous gas are also observed surrounding some of the bright novae, and the fact that these "temporary stars" very suddenly rise to brightnesses of 100 times their normal values suggests some sort of an explosion whereby some part of their masses are lost. The frequency with which these apparent conflagrations occur further suggests that in the calculated lifetimes of the stars such phenomena are by no means uncommon. There is some possibility, on the other hand, that mass may be gained from the same source to which a superficial explosion of this type may be due—that is, assuming that such a star owes its explosion to an encounter with a planet or nebulosities which it may also add to its own mass. On the whole, therefore, it seems reasonable to suppose that, aside from the mass lost by radiation, the mass gained may counteract that lost—such as in the form of atoms, of positrons and electrons, either by explosions, or even by the genesis of planets similar to those, including the earth, which revolve periodically around the sun.

In calculating the ages of the stars, graphically illustrated in Figs. 2 and 3, it is tacitly assumed that a star having a mass of 100 or 10 times that of the sun may continually, and continuously, radiate mass until it is much less massive than the sun. The mass-luminosity relation itself argues against the existence of stars with appreciable masses but without active material which can be transformed into radiation. If only a part of the material of which a star is constituted should be transformable, the luminosity of the star would no longer conform to the mass-luminosity relation, when its energy stores became somewhat depleted and when the star began to fade.

Of the six possibilities that the ages given in Table I may not represent fairly good approximations to actual facts, the last may perhaps lead to the most serious differences. Although the process of fission involves the loss of mass other than by radiation, this process apparently merits special attention for the reason that it may be one which is actually taking place among the stars; and it may affect the calculations considerably. According to Fig. 3, the ages of the stars for masses greater than about four times the sun's mass should be decreased by about 40 per cent. when the mass is halved; and the fact that the representation for smaller masses begins to depart considerably from the initial straight line indicates that for these stars an amount in excess of 40 per cent. and increasing with decreasing mass until a uniform amount of more than 10 times must be subtracted from the ages, when the mass is halved. In other words, loss of mass by fission always makes the calculated ages too large, the percentage of error increasing with increasing age and decreasing mass. Furthermore, when the two stars resulting from fission are not equal in mass, the percentage of error in the fifth column of Table I decreases with increasing differences between the two components. This is evident from

the fact that the hypothetical error is zero when one component contains all the mass.

These discussions seem to be more eloquently justified by the observed fact that, among the brighter ones at least, one star out of every three or four can be resolved into two or more components. In some cases the components are far enough apart as to be resolvable by the telescope; but representatives of another class, quite distinct from the visual doubles, are identified by means of the spectroscope or by periodic eclipses. These, the spectroscopic binaries and the eclipsing stars, are distinguished by the fact that their components are much closer together and, in some cases, almost in actual contact. Spectroscopic binaries are eclipsing when the planes of revolution are so oriented that one star passes between the earth and the other and thus partially intercepts its light. If all the stars are decreasing in mass and in heat content, the question then arises as to the progenitors of this class of very close doubles. In this connection, the only class of stars which has hitherto demanded any attention is the Cepheid variables. Although the luminosities of these stars apparently rise and fall with periods similar to those of eclipsing binaries, there are few astronomers who believe that they are actually double.

The most generally accepted opinion as to the causes underlying the variations of Cepheids seems to be that they are really variable in size; or, in other words, they are pulsating. Although this theory—the pulsation theory—claims the support of such well-known astronomers as Shapley and Eddington, there is a minority of others who believe that Cepheids represent a stage in the lives of these stars preceding fission. This theory, of which Jeans is perhaps the ablest champion, is that their shapes are similar to that of a dumb-bell and that they owe their variations to rotations of such peculiar figures about the smaller axes. By secular condensations about the two nuclei of the dumb-bell shaped figure, Jeans believes that the components of a binary system are eventual consequences. Both the pulsation and the fission theory, therefore, admit that the evidence is decidedly against any conjecture of actual duplicity of these stars; and the fission theory seeks also to explain the origin of the close binaries, an undertaking not attempted by the pulsation theory. Some reasons for believing that these stars actually are in the act of dividing into binary systems are: (1) The spectroscopic evidence points rather to rotation than to pulsation. (2) The mean densities which can be computed are approximately what would be expected of an embryo binary system where the components have not yet separated. (3) The mean radii of Cepheids compare favorably with the separation of the components of binary systems with similar periods. (4) Slight evidences of correlations of colors and brightnesses of short-period binary systems with Cepheids are to be found. (5) The galactic distribution of the two classes of objects compare favorably. (6) The agreement of periods is as good as could be expected. Illustrations of the possible transitional stages and a somewhat fuller discussion of related problems are to be found in an article on "Variable Stars" by the writer in the Annual Report of the Smithsonian Institution for 1932, pages 121–131.

If there are stars which are in the act of dividing, as there are some reasons for believing, the course is to decrease the net output of radiant energy of the universe as a whole. This follows from the fact that the combined flux of energy from both the new stars resulting from fission is less than that of the parent star before fission took place. The evidence seems to favor the conclusion that only the brighter and the more massive stars

can ever break up, if indeed division ever does actually occur. Cepheids are rarely, if ever, less than 100 times as bright as the sun; and from this fact it may be supposed that no fission ever occurs among those stars whose luminosities are less than 100 times that of the sun or whose masses, by the mass-luminosity relation, are less than four times the sun's mass. It is perhaps of some significance to note that in Figs. 2 and 3 sharp deviations from what would otherwise be straight lines occur for luminosities and masses slightly below the above values. In case a star of four times the sun's mass, having a luminosity of 100 suns, should break up into two stars, each having twice the sun's mass, each of the components should give only as much light as 14 suns such as ours. In other words, the light-giving power of the parent star has now fallen from 100 times to 28 times the sun's luminosity after fission has taken place. If the two new stars resulting from fission are of unequal mass, the combined light will be more than 28 times but certainly less than 100 times the sun's brightness if there is no violation of the mass-luminosity relation. In any case, therefore, the result is to conserve the lavish output of energy by the stars in general. If this energy radiated away into space is actually lost, nature has here a means of checking these leakages of the universe.

When the age of the earth is estimated to be more than 2,000,000,000 years, it is also understood that this figure carries all the weight generally attributed to actual observations. The presence of radioactive elements and their products in certain definite ratios found among the older rocks of the earth's crust constitutes an increasing wealth of circumstantial evidence as to the ages of these rocks when these evidences are weighed against laboratory measurements of the rate at which the parent elements are decomposed; and the observations apparently justify the conclusion that there was a time much farther back than 2,000,000,000 years when the earth was in a molten state.

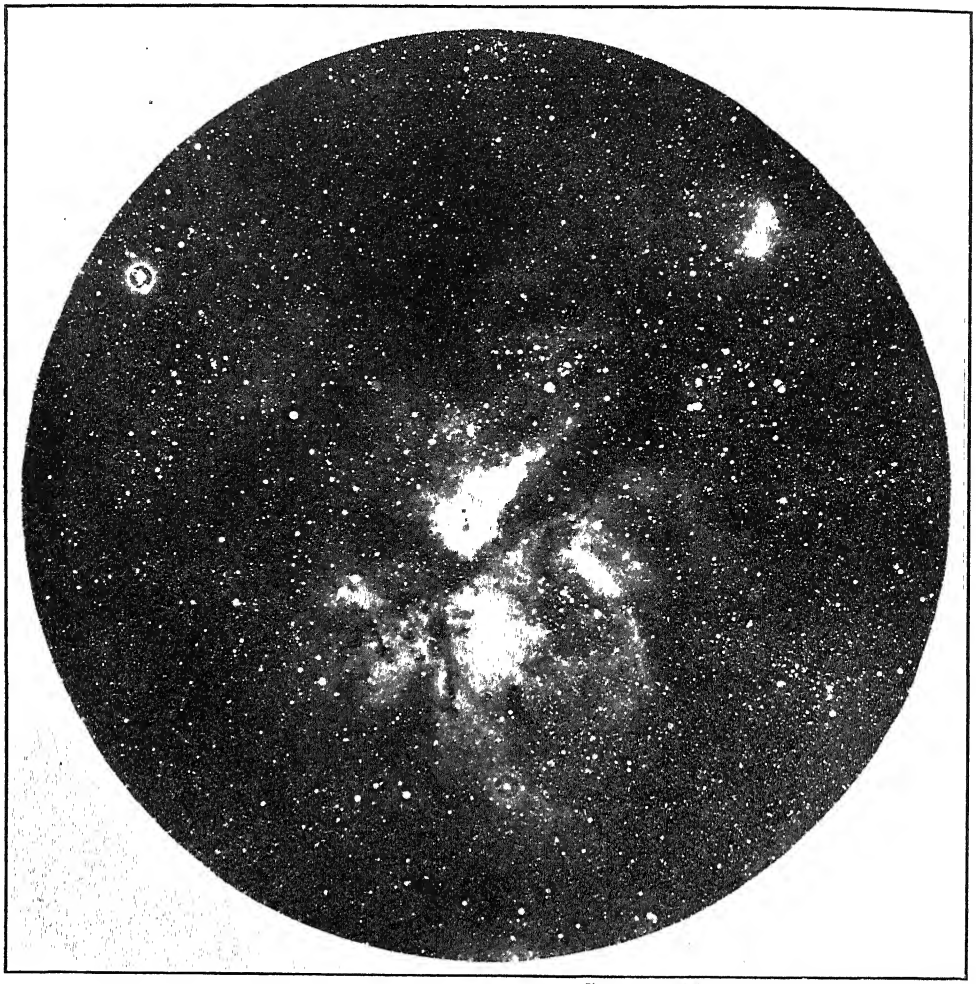
From the stars, however, such direct and eloquent testimony is not yet available. The only messages man ever receives from these far-away suns are bound up in very limited quantities of light which his instruments intercept; and he is asked to decipher and to learn their codes. Meager as these may seem, they bear testimony of the constituency of the atmospheres of these stars, of their motions in the line of sight, of their temperatures, of their sizes, of their densities, of their masses, of their intrinsic luminosities and distances; in short, the beams of light which the astronomer collects and analyzes reveal to him the general physical conditions which exist in stars so far away that the light he studies may itself be hundreds of years old. On the other hand, man has been on the earth only about one million years; and in this interval of time he has about the same chance of observing secular changes among the stars as a genus of insects with a current life of one second would of predicting the changes and the span of life of any individual of the genus *Homo sapiens*. It is necessary to assume further that only in the last 0.0001 part of this second has this hypothetical insect been gifted with the ability to make reliable observations for at most can man claim detailed observations of the stars over a period of only a century—about 0.0001 part of his terrestrial existence. In this short interval of time he has assured himself that the stars have enormous supplies of energy, the output of which he is able to measure. If he can rely on the theory of relativity, as he believes he can, he can further specify just how many tons of light a star radiates in one second and compare this amount with the total mass of the

star. These are about the limits of his observations in attempting to measure the ages of the stars, and from data such as this Table I has been constructed. The time intervals here between successive magnitudes, however, undoubtedly carry considerable weight, at least much more than the absolute time values themselves.

If ramifications of the problem are to be relied upon for further clues of evidence, star counts should perhaps afford some cause for optimism. It is then necessary to assume a homogeneous aggregate of stars, sufficiently large, and that among these the birth rate is fairly uniform over such eons of time as are indicated here. Under these conditions, the number of stars between successive intervals of absolute magnitude should be proportional to the corresponding intervals of time required for a star to undergo the stages in its evolution represented by such magnitude differences. Thus in Table I about 43,000,000,000 years elapse between absolute magnitudes of -5 and -4 and about 64,000,000,000 years between magnitudes -4 and -3. Accurate star counts, therefore, should reveal about 43 stars between absolute magnitudes -5 and -4 to 64 between -4 and -3. Counts by Seares at Mount Wilson indicate for the brighter stars much more rapid increases in numbers with decreasing brightness than is to be inferred from Table I, but for the fainter ones the increase in numbers is much slower than is specified by Table I. Among the stars which are intrinsically faint such stationary or abrupt falls in numbers, for successive intervals of decreasing brightness, might be understood to represent an upper limit to the age of the group from which the counts are made. The question of homogeneity and other factors of uncertainty, however, are not to be lost sight of here; and, under all the conditions here implied, it is an open question as to how far actual star counts might be expected to agree with successive time intervals of Table I. More ideal counts could certainly be made from such star groups as the Magellanic Clouds of the Southern sky or perhaps from some of the nearer loose clusters.

One further question, without some consideration of which the present discussion can hardly be regarded as complete, takes cognizance of the extravagant flow of light and heat away from the stars into the realms of unfathomed space. It is estimated that in the Milky Way system there are about 50,000,000,000 stars and that the sun in energy output is little, if any, above the average. Consequently, if the sun loses 46,000,000 tons of heat and light every second, that lost by the whole system over the eons of time indicated in Table I is almost beyond the bounds of comprehension. At least, unless indeed nature is in some way rewinding it, the day will come when the universe will be no more than a great cemetery of worn-out suns whose last vestiges of ancient glories have forever faded.

If the calculations made here mean anything, there seems to be no escape from the conclusion that an intelligent being, gifted with equipment perhaps much more advanced than that of the present day, say 20,000,000,000,000,000 years hence, would probably see less than a dozen of the magnificent stars now visible to terrestrial man. At this distant date, not one of the luminous giants now lighting the nocturnal sky would have a mass as large as one tenth of the sun's present mass; and of these no less than 100,000 would be required to radiate as much light and heat as the sun now radiates. If, on the other hand, the universe is rewinding itself and new stars are yet being born, then in attempting to portray what our future astronomers would observe, situated perhaps on some far-away planet yet un-



Courtesy of Harvard College Observatory

FIG. 4. NEBULAE ABOUT η CARINAE

PHOTOGRAPHED WITH A 24-INCH BRUCE TELESCOPE AT THE BOYDEN STATION OF HARVARD COLLEGE OBSERVATORY IN SOUTH AFRICA. EXPOSURE 80 MINUTES.

born, we should have more cause for optimism.

The question yet remains, however, as to whether or not the universe is actually running down; and on this problem researches now in progress will probably paint a much clearer picture within the next few years. Investigations conducted by Anderson at the California Institute of Technology seem to support the view that positively charged positrons and the negative electrons, both very minute and ultimate particles of matter, are produced in pairs from the energy of the very short γ rays when they impinge on a material surface. If such is indeed the case—and there seems to be no room for doubt—and if light and heat from the stars represent the apparent transmutation of matter into energy, then science seems assured that the interaction between matter and en-

ergy is a reversible one; that is, energy may be transformed into matter as well as matter into energy. Furthermore, the old theory, that both the mass and the energy content of a system are forever absolutely fixed, now takes on a new and a wider meaning. It denies that either the mass or the energy of a body is absolutely invariable; rather it is the content $E + mc^2$ that is constant.

Further inquiry yet arises, first, as to whether rays of light from the stars act in the same manner as the very short γ-rays and, second, as to whether the energy content of these rays necessarily require the presence of a material agent before this energy can be transformed back into matter. Neither question can be definitely answered at present; but a tentative conjecture that the only difference in effect between the longer rays of starlight and the γ-rays is a quantitative one is probably not far wrong. Moreover, the astronomer is also sure that, in certain directions at least, the depths of space are filled with great clouds of very tenuous gases; and it may be that the starlight captured by these clouds is reconverted into matter, thus adding to the material content of these clouds which eventually may develop into many stars. Such a cloud, illuminated by light from the associated stars and so great in extent that years are probably required for light (moving with a speed of 186,320 miles per second) to transverse it, is illustrated in Fig. 4. If matter is transformed into energy in the hot interiors of the stars, what contrast more fitting for the transformation of energy into matter could be sought than these frigid realms of unfathomable space? The ideal philosophy apparently demands an eternal universe susceptible neither to death nor to decay, but science is yet confronted with the challenge as to the destiny of all the energy from the stars not intercepted by the material universe.

The fate of terrestrial man and his earthly abode, however, can hardly contemplate the lapse of such eons of time as the 20,000,000,000,000,000 years mentioned above. Man is firmly convinced that any given form of matter is quite ephemeral; there is no state of the universe nor of any of its parts that is eternal and everlasting. The frequency of novae, like S Andromedae and the many others which blaze up from time to time, suggests that in the course of the life of every star such conflagrations are by no means uncommon. This point is not overemphasized when it is predicted, therefore, that long before the sun shall have been turned into darkness by age and the flight of time, it and all "the heavenly bodies shall be dissolved with intense heat, and the earth and all the works that are therein shall be burned."

EDWARD CURTIS FRANKLIN

THE PROGRESS OF SCIENCE

EDWARD CURTIS FRANKLIN, 1862–1937

WITH the passing of Edward Curtis Franklin on February 13 one of the great personalities of this generation in chemistry in America has gone. Few men whom one meets in an entire lifetime, within or without academic circles, have lived a life so full of adventure and fine friendships, and adorned by a personality of such singular simplicity and charm and a record of such outstanding achievement.

If he had lived another fortnight he would have reached the age of seventy-five. He was born in Geary City, Kansas, on March 1, 1862, the eldest son of Thomas Henry Franklin, a Philadelphian who went West in 1857, erected a sawmill and made lumber from the abundant growth of elm, oak and walnut on the bottoms of the Missouri River. Here he spent his boyhood, fished and swam in the sloughs and river, roamed the hills and river bluffs and learned to hunt and trap wild game. He and his younger brother, Will, who had a notable career as a physicist, revealed their scientific bent in early youth, making Leyden jars and batteries, experimenting with chemicals in a corner of the sawmill office, having unending amusement out of a James Quenn microscope bought for them by their father, and collecting crinoids and other fossils from the limestone bluff along the river. Later on they erected a telegraph line two miles long and became quite expert in sending and receiving by the Morse Code. With the help of their father they made a pair of Bell telephones from directions they found about 1877 in the SCIENTIFIC MONTHLY, then published as the *Popular Science Monthly*. These were used on the telegraph line and later on a line from their home to the sawmill. The telephone invented by Alexander Graham Bell was first exhibited at the Centennial Exposition in 1876, and it is interesting that these two young enthusiasts, both under fifteen, had a crude reproduction working out in Kansas a year or so later.

Entering the University of Kansas in 1884 at the age of twenty-two, he graduated as a major student in chemistry, and two years later went abroad with his brother for a year of graduate work—he to work in chemistry, his brother in physics. They were not oversupplied with funds but had read shortly before about how to do Europe on fifty cents a day and felt that if any one could do it they could. Afoot and by train and Rhine boats they crossed Germany to Switzerland, climbed some of the great peaks of the Alps and made their way back to Berlin. Here Professor Franklin worked for a year in Tiemann's laboratory and attended lectures by von Hofmann on general and organic chemistry chiefly to learn the lecture technique of that great teacher, by Helmholtz, Kundt and Max Planck. Returning to the University of Kansas he taught for two years, then went to Johns Hopkins to work especially with Professor Remsen, where he received the doctorate in 1894. The offer of an associate professorship lured him back to Kansas, but two years later, not yet sure that he should follow an academic career, he accepted a position as chemist and co-manager of a gold mine and mill in Costa Rica. The following year he returned to the University of Kansas, where in 1898 he was advanced to a full professorship, and remained until he went to Stanford in 1903. Except for an absence of two years, on leave of absence from 1911–13 as chief of the division of chemistry of the Public Health Service in Washington, he remained continuously in active service at Stanford until his retirement as professor emeritus in 1929.

Many distinguished honors came to him in later life—among them honorary degrees from Northwestern, Western Reserve and Wittenberg, the Nichols Medal, the Willard Gibbs Medal, the presidency of the American Chemical Society, the invitation to South Africa in 1929 as the honorary guest of the British Association for the Advancement of Science and election to the National Academy of Sciences and the American Philosophical Society.

Outside of his work of teaching and research, nothing contributed more to the joy of living nor stored his mind with happier memories than his love of an outdoor life. He was especially fond of mountain climbing, camping, fishing and hunting, and, in later years, of motoring. I have rarely seen any one so skilful at putting a diamond cinch and a well-balanced pack on a stubborn packmule. A part of nearly every summer for many years was spent in the mountains of Colorado and California, most of whose great peaks were climbed by him. Among these are a number over fourteen thousand feet and a score or more around thirteen thousand. One of the notable trips in the long record of summer excursions to which he often referred was in the summer of 1889 when for nearly three months he was in the Colorado "Rockies" with a party from the University of Kansas, including Chancellor Snow, Will Franklin, Vernon Kellogg, Frederic Funston, Hubert Hadley, William Allen White and a few others. They camped and packed through the wilder regions, climbed many lofty peaks, explored new country and had many thrilling adventures. That was a great company of young men, nearly all of whom became nationally known in later years. The lure of great mountains never left Professor Franklin, even after he had reached the age when such extreme physical exertions are hazardous. In 1929, at the age of sixty-seven, returning from South Africa along the east coast, he got within about thirty miles of Mt. Kilimanjaro, which rears its majestic summit nineteen thousand feet—a sight to stir the emotions of every true mountaineer.

Since the summer of 1931, on four extended transcontinental tours by automobile, he traveled a distance more than equal to twice around the globe. His last trip, made alone last autumn, took him eastward to the Atlantic Coast, southward to the southernmost tip of Florida and westward through the South, lecturing before many of the sectional groups of the American Chemical Society, and covering over thirteen thousand miles—at 74!

The scientific work of Professor Franklin dealt mainly with what is now known as the ammonia system of acids, bases and salts. This was begun at the University of Kansas and was continued throughout the ensuing three decades which he spent at Stanford. It led not only to the synthesis of a large number of compounds new to science by him and his coworkers, but to new concepts of fundamental importance in regard to the structure and relationships of many nitrogenous compounds out of which has grown a new system of compounds in chemistry. His investigations in this field, embodied in a large number of important papers and a recent monograph, will stand as one of the major contributions to the chemistry of this period.

No review of the career of Professor Franklin would be complete without reference to his ability as a teacher. His lectures were models of direct, orderly, clear, precise thinking, and were made peculiarly effective by many experimental demonstrations. Here he was at his best! His native resourcefulness and ingenuity and mechanical skill were a constant source of admiration to all who came under his instruction in the classroom or research laboratory. Most of the very complicated and delicate glass apparatus which had to be developed to meet the experimental conditions in working with liquid ammonia were made

by his own hands. They are fine examples of the glass-blowing art.

After the mantle of a professor emeritus fell to him he retained his office and private laboratory in the chemistry building. Here he continued his work and through the open door students and friends, old and new, went for a word of greeting or for an interesting discussion over a wide range of topics. A pleasant chat with him, or a bit of banter, which he enjoyed so much, was a source of good cheer which will be missed by all who have had the privilege of frequent contact with him. There was a delightful informality about him which was wholesome, friendly, even playful and always sincere. It is little wonder that he had so many loyal and intimate friends—for friends flocked to him like iron filings to a magnet. They, too, meant much to him. An evening in a congenial company, anywhere, was an unfailing source of pleasure to him. And whether around a Sierra campfire or in the carefree company of the club or about his own fireside, he was always the same delightful and stimulating companion whose alert and inquiring mind was constantly seeking to satisfy its zeal for new impressions and ready to draw upon those which had been stored away through a remarkably eventful and varied and fruitful career.

His was truly an abundant life—full, to a fine old age, of adventure, of an enduring love of nature, of lasting friendships and of the fruits of a surpassing career in teaching and research.

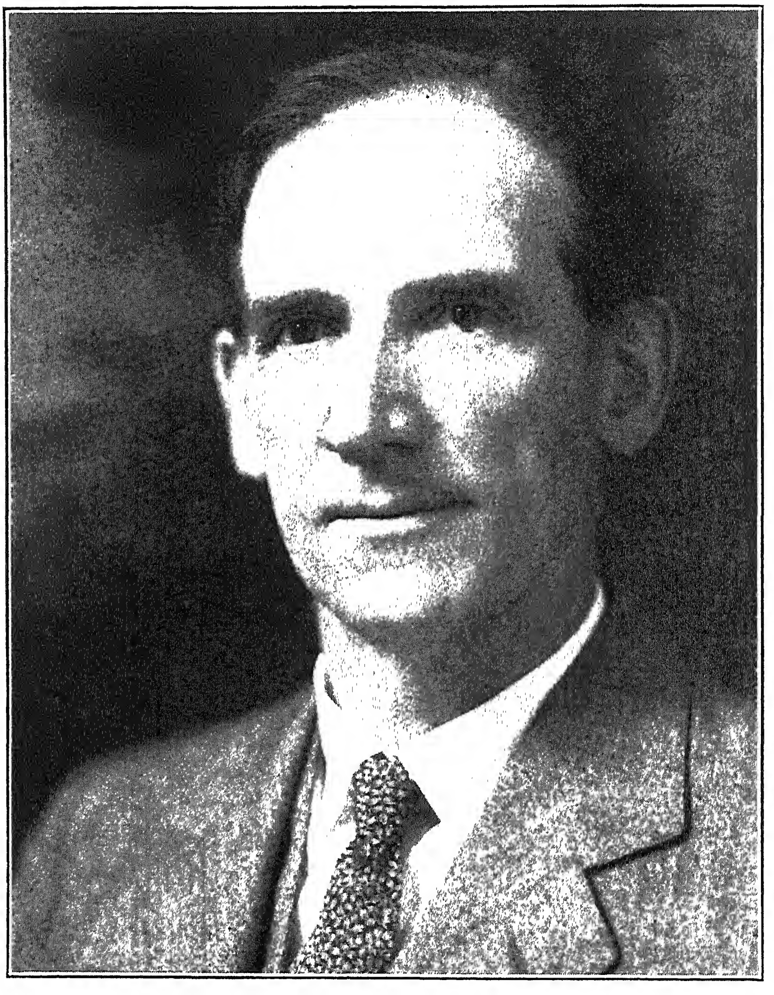
ROBERT E. SWAIN
STANFORD UNIVERSITY

DR. COTTRELL, RECIPIENT OF THE WASHINGTON AWARD

THE award for 1937 of the Washington Award Commission has been bestowed on Frederick Gardner Cottrell, of Washington, D. C., "for his social vision in dedicating to the perpetuation of research the rewards of his achievements in science and engineering."

John Watson Alvord, a Chicago sanitary engineer, established the Washington Award in 1916, with the idea that there should be some such means of recognizing outstanding engineers who render unusual service in promoting the public welfare. The award is administered by the Western Society of Engineers in cooperation with the American Society of Civil Engineers, American Institute of Mining and Metallurgical Engineers, American Society of Mechanical Engineers and American Institute of Electrical Engineers. Seventeen men elected for the purpose compose the Award Commission. The award is made annually, providing the members of the commission agree on a deserving candidate, as an honor conferred on a prominent engineer by his fellows for accomplishments which preeminently promote the happiness, comfort and well-being of humanity. There have been several years when no award was made, and the preceding thirteen noted American engineers to receive it included representatives of many branches of engineering.

Dr. Cottrell has achieved much in his scientific career. He is perhaps best known for his invention and subsequent perfection of the precipitator which bears his name. This was first conceived as a means for taking sulfuric acid fumes out of the atmosphere in a manufacturing plant and received its first commercial trial in the important Riverside Cement Company's plant, where through its use the company was enabled to remain in business in the midst of an important citrus fruit area. The precipitator effectively removed an amount of dust, totaling tons per day, which up to that time had been distributed through the stack gases over a wide agricultural area, doing much damage. Since then there have been many installations of the Cottrell precipitator, the largest of these



DR. FREDERICK GARDNER COTTRELL

being at the smelter of the Anaconda Copper Company in Anaconda, Montana, which includes the largest smokestack in the world. An important byproduct recovered from this installation is arsenic, so important in insecticides and fungicides. One of the newest problems solved with the precipitator is the recovery of fly ash in plants burning powdered coal. The physical character of this ash is such as to make it not only disagreeable but almost a menace if permitted to remain in the air.

Dr. Cottrell, widely known as a chemist and metallurgist, has served as director of the U. S. Bureau of Mines and director of the Fixed Nitrogen Research Laboratory of the U. S. Department of Agriculture. He is interested in all manner of scientific developments, and besides founding the Research Corporation has since organized Research Associates, Inc., of which he is the president. Dr. Cottrell has gone a step further than the majority of his colleagues in dedicating to science through the operations of the Research Corporation the principal part of the income from his patents. During the years this has run into several hundred thousand dollars, which might have

been his own personal reward for his achievements, had he not preferred to set it aside, as he has, that it might perpetuate research, be available to undertake the development of worth-while ideas of inventors who could not perfect their inventions and in general be used in the interests of public welfare.

To his colleagues Dr. Cottrell is known as a stimulating enthusiastic research worker. He has little interest in pecuniary rewards from such work and takes his greatest delight in seeing well done some piece of research that promises practical application and wide utilization with concurrent benefit to the people. His best friends may affectionately describe him as a butterfly chaser at times, and there must be some brilliantly hued butterflies to pursue when one is so interested in all that goes on. He is beloved of those who work with and associate with him, well informed in a multitude of diverse fields and a worthy representative of his profession for this or any other honor.

H. E. Howe

Journal of Industrial and Engineering Chemistry

THE 125TH ANNIVERSARY OF THE ACADEMY OF NATURAL SCIENCES

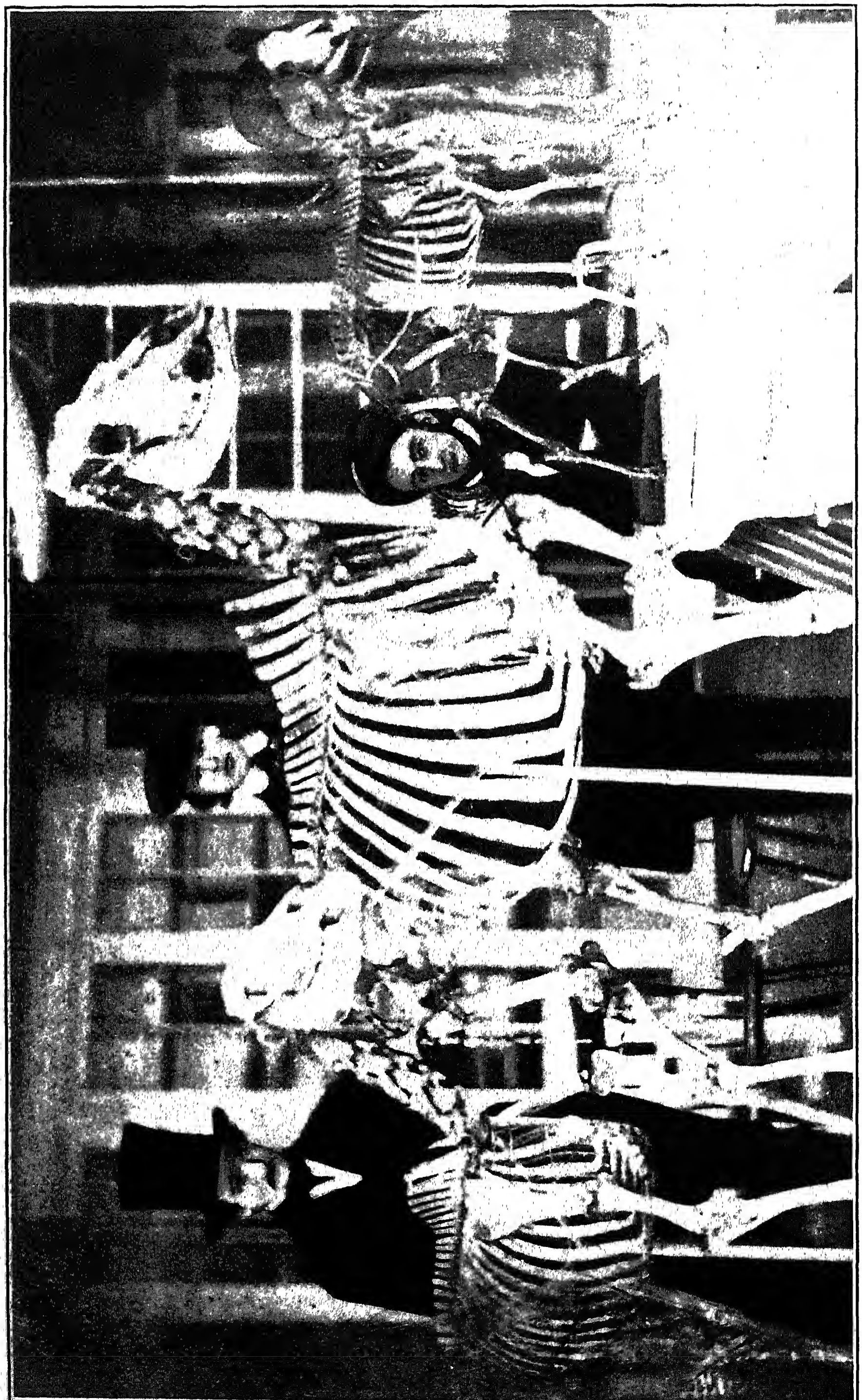
The one hundred and twenty-fifth anniversary of the founding of the Academy of Natural Sciences of Philadelphia—the oldest institution of its kind on this continent—was marked by a series of events and exhibits, the most notable of which was the International Symposium on Early Man and the opening of the Hall of Early Man. Although the symposium was held on the four days preceding, the actual date marking the anniversary of the academy's incorporation was March 21.

Two years ago, the academy, sensing a need to make itself more vital in the life of the community, undertook an Educational Development Program, that has resulted in the formation of a Department of Education and the re-establishment of the Department of Geology and Paleontology. Seventy-five years before, in the pristine glory of Joseph Leidy, Isaac Lea and Edward D. Cope, the academy had been America's center of these studies. After a survey by Dr. Edgar B. Howard, plans were laid to again establish the academy's leadership in geology and paleontology. New space was appropriated to house the study collections of the pioneers; the Carnegie Institution of Washington appointed research associates to work at the academy, and in the Southwest expeditions, under the leadership of Dr. Howard, acting curator of geology and paleontology, discovered important evidence of Early Man's existence in North America.

In November, 1936, it was decided that no more appropriate way of celebrating the one hundred and twenty-fifth anniversary could be pursued than by holding an International Symposium on the subject of Early Man.

Accordingly, Dr. John C. Merriam, president of the Carnegie Institution of Washington, accepted the chairmanship of a committee to form a program. Dr. Edgar B. Howard agreed to act as secretary, and Dr. George Grant MacCurdy, director of the School of Prehistoric Research, Dr. Edwin G. Conklin, executive officer of the American Philosophical Society, and Dr. Hellmut De Terra, research associate of the Carnegie Institution and associate curator of geology and paleontology of the academy, consented to assist them. Invitations were sent to scientists throughout the world to join in the symposium.

In order that the public might better participate and understand the purpose of the symposium and the general subject of Early Man, the academy's exhibits department arranged a Hall of Early Man, wherein the exhibit material brought to the academy might be dis-



MUSEUM OF THE ACADEMY OF NATURAL SCIENCES IN 1838

THE OLD BUILDING AT TWELFTH AND SANSOM STREETS, PHILADELPHIA. THIS IS BELIEVED TO BE THE EARLIEST PHOTOGRAPHIC RECORD OF AN AMERICAN MUSEUM INTERIOR. THE YOUNG MAN IN THE CENTER IS TRADITIONALLY SUPPOSED TO BE JOSEPH LEIDY.

DR. EDGAR B. HOWARD AND JOHN COTTER
INSPECTING THE STONE TOOLS WHICH HAD JUST COME FROM THE SAN DIEGO MUSEUM FOR EXHIBITION IN THE HALL OF EARLY MAN.

played with graphic understandable labels. This hall was opened on March 17, before a large audience of the academy's members and the visiting delegates to the symposium.

As outlined in the preliminary announcement that accompanied the invitations, the purpose of the symposium and its related exhibits was to focus the attention of the scientific and lay world on the advances being made in the study of Early Man. In its final form the program consisted of thirty-three original papers which were read over a period of four days and which were followed each afternoon with round-table conferences on European, Asiatic, North American and African chronology and a discussion on typology and distribution of Folsom and Yuma points.

To the symposium came more than 400 scholars. These included G. H. R. von Koenigswald, of Java; Dorothy A. E. Garrod, of England; Aleš Hrdlička, of the U. S. National Museum; Père Teilhard de Chardin, of China; V. Gordon Childe, of Scotland; Earnest A. Hooton, of Harvard; Josef Kostrzewski, of Poland; Robert Broom, of South Africa, and Kaj Birket-Smith, of Denmark.

In every respect, those attending the symposium might have been described by the very words of the founders themselves, "Gentlemen, Friends of Science and of a rational disposure of their leisure time."

Could any of the founders glimpsed at the opening session on March 17, they would have known that their initial meeting a century and a quarter before had laid a firm foundation.

JOHN H. FULWEILER
THE ACADEMY OF NATURAL SCIENCES
OF PHILADELPHIA

THE NATURAL HISTORY EXPEDITION TO SUMATRA

An expedition to collect rare wild animals of Sumatra, Netherlands Indies and the neighboring regions of the Far East and to gather geographic and natural history information and photographs has been sent out under the joint auspices of the National Geographic Society and the Smithsonian Institution.

The party, which is already in the field, is headed by Dr. William M. Mann, director of the National Zoological Park, and the animals which are captured will be added to the collections there. Accompanying Dr. Mann are Mrs. Mann; Dr. Maynard Owen Williams, staff representative of the National Geographic Society; and Malcolm Davis and Roy Jennier, of the National Zoological Park staff.

This expedition is unusual in the fact that it not only will bring back Far Eastern wild animals to the United States, but it also carried a large collection of North American wild animals from the United States to Sumatra. These animals, which are as rare in the Far East as are Far Eastern animals in America, will be presented by Dr. Mann as gifts to zoological parks in cities of Sumatra and elsewhere.

The North American animals include ten alligators, two jaguars, two mountain lions, three opossums, two raccoons, two black bears and five hellbenders, which are a species of large salamander from the Alleghanies. They have the peculiar characteristic of breathing through the skin, having neither lungs nor gills. These animals, taken from surplus collections at the National Zoölogical Park, were shipped direct from New York to Belawan-Deli, Sumatra, via the Cape of Good Hope, under the care of Mr. Davis and Mr. Jennier.

To feed the animals on the 40-day voyage the National Zoo sent with them 1,000 pounds of frozen beef, 100 pounds of frozen fish, 500 pounds of special bear bread baked in the zoo's own bakery, and a barrel each of apples, sweet potatoes and carrots. Most of the animals had been in the National Zoo almost since birth, so it was expected that confinement on the voyage would be no hardship for them. The two jaguars were born in the zoo 18 months ago.

Dr. and Mrs. Mann and Dr. Williams went to Sumatra by way of Japan, Shanghai, Hong Kong and Singapore, visiting zoological parks en route. The party will spend about four months collecting in Sumatra and other nearby islands. It is equipped with special "mercy traps" and a few small cases in which to carry small, delicate creatures. Heavy traps and cages for the larger jungle beasts will be built in the field.

The region to be visited is at present only poorly represented by animals in the National Zoological Park, Dr. Mann feels. He will confer with game officials and naturalists who are familiar with local conditions and will collect whatever he can of the desired specimens.

Mammals, reptiles, birds and a few fishes will be the primary objects of the collectors, but in spare time Dr. Mann hopes also to collect insects and possibly a few botanical specimens.

After the work is completed in Sumatra, the expedition expects to visit the Netherlands island of Ceram, almost 2,000 miles to the east, and possibly some of the East Indies islands not under Netherlands jurisdiction. It is planned also to touch at Bangkok, Siam. The party will return through the Indian Ocean and the Mediterranean.

M. K.

ENGINEERING PROBLEMS IN FLOOD CONTROL

Floods are caused by high rates of run-off resulting from heavy rainfall, melting snow or a combination of the two. The rate of run-off from a watershed is affected by the amount and intensity of the precipitation, stored water

in the form of snow, temperature, size and shape of watershed, geology and soils, topography, vegetative covering and the degree of saturation of the watershed at the beginning of heavy rainfall or rapid melting of snow.

The influence of each of these various factors upon the rate and volume of flood flow makes a very complex relationship, which varies greatly on different watersheds. In planning flood control improvements the engineer, in cooperation with other specialists concerned in watershed improvement, must evaluate the effects of these factors on the watershed upon which he is working, and determine the amount of run-off that may be expected; how much of it can be conserved and used for municipal water supplies, irrigation, power and other uses; and how much must be disposed of as flood water. Of the factors affecting run-off, only the three last named above can be modified by man: (1) The type of vegetative cover can be controlled; (2) the degree of saturation can be influenced by drainage works; (3) the topography is modified in some degree by erosion and by flood-control works.

Floods can be modified or controlled by (1) channel enlargement or improvement to increase capacity; (2) levees to augment channel capacity; (3) reservoirs to store water until the flood crest has passed; (4) erosion-control works and vegetative cover to retard flow into stream channels.

Reservoirs to be effective must be so located that they will retard sufficient run-off from the area above that to be protected to enable the water channels to carry the remaining flood flow without damage to the protected area. In the past it has been assumed that reservoirs for flood control must be used exclusively for that purpose—that it was not feasible to construct a reservoir for flood control and at the same time use it to store water for irrigation, water power, recreation or other purposes. Now it has become apparent that frequently, especially in connection with larger projects, by careful planning of operation a part of the storage available can safely be used for purposes other than flood control.

Levees are generally used to confine the flood flow in a comparatively narrow floodway through the bottomlands of a stream. On most streams a large increase in capacity can be obtained more cheaply by use of levees than by enlarging or straightening the channel proper.

The improvement and enlargement of stream channels to control floods is usually limited to comparatively small streams or watersheds. The amount of run-off from large watersheds is so great that the cost of constructing channels to carry all flood run-off is prohibitive. Channel improvements are frequently made in connection with the use of reservoirs and levees to reduce the size required for such improvement. Clearing stream banks of obstructions and smoothing them or lining them with concrete reduces the friction of the flowing water and in many instances materially increases channel capacity.

In planning flood control improvements it has been usual to charge the cost of the improvements back to the property protected—where material benefit could be shown—although it was appreciated that there are many less tangible benefits of great value to the community as a whole, such as prevention of the interruption of traffic, interference with business, impairment of public health and other similar benefits. Recently there has been a tendency to give increasing consideration to the indirect benefits and to the equity of distributing the costs of flood control works over wider areas or having part of the cost paid by state or federal governments.

S. H. McCrory,
Chief
Bureau of Agricultural Engineering
U. S. Department of Agriculture

THE PROJECTED WIND TUNNEL AT THE MASSACHUSETTS INSTITUTE OF TECHNOLOGY

The Massachusetts Institute of Technology will shortly start the construction of a high-performance wind tunnel to be dedicated as a memorial to the Wright Brothers. Gifts from persons interested in the advancement of aeronautics have made this possible.

With the increasing speed and size of air craft, our existing wind tunnels have become obsolete. In this country, only the great Langley Memorial Laboratory of the National Advisory Committee for Aeronautics has equipment operating near "full scale" Reynold's Number.

The scale effect in model testing depends on the Reynold's Number, the product of velocity and wing chord divided by kinematic viscosity. The Reynold's Number of airplanes has increased more than 200 per cent. since 1918, and this growth rate may be expected to continue. Model data to be safely extrapolated should be taken for conditions corresponding to a Reynold's Number above 10^6.

The power required to obtain the wind in a tunnel varies as the cube of the velocity, the square of the diameter and as the density. It is, therefore, more economical to obtain high Reynold's Number by increasing density than by increasing speed or size.

The projected Wright Brothers' wind tunnel will be a closed circuit of welded ship steel with external frames. Pumped up to 4 atmospheres pressure, the Reynold's Number will be about 6×10^6. The throat of the Venturi section will be an ellipse of 10 feet major axis, suitable for models of the order of 7 feet in span. A 2,000 H.P. steam turbine will turn the fan.

The same tunnel when pumped out to 1/4 atmosphere pressure, corresponding to about 35,000 feet altitude, will have a wind velocity of 400 miles per hour. Aerodynamic research at such a speed is considered necessary if future airplanes are to fly in the sub-stratosphere.

The projected tunnel will be unique in that it combines means for operating at a high Reynold's Number to study phenomena of skin friction, turbulence and flow separation, as well as means for the study of high velocity phenomena. It is considered probable that changes in the design of wings must be made when the air speed is such that local velocities approach the velocity of sound.

Due to the use of a variable pressure, access to the model in the tunnel will be extremely inconvenient, and a new type of suspension of the model has been devised, by means of which electrical measuring instruments outside the tunnel will indicate the aerodynamic force of the wind on the model. The principle of these balances is that of the well-known electromagnetic micrometer, by which a very small displacement of an elastic element unbalances the magnetic flux in an air gap, giving rise to unbalance in an A.C. bridge circuit.

J. C. Hunsaker
Massachusetts Institute of Technology

THE SCIENTIFIC MONTHLY

MAY, 1937

AN ASTRONOMER LOOKS AT THE MODERN EPOCH

By Dr. JOHN Q. STEWART

PRINCETON UNIVERSITY OBSERVATORY

(1) Introduction

In observatories and universities a livelihood is provided for astronomers who look at and think about planets, stars and galaxies. What business have astronomers to look at, to criticize, the modern epoch? Astronomy had much to do with its inception. Ways of living and of thinking based on the successes of natural science *are* modernity. That is all.

The modern period differs from its predecessor medieval principally in knowledge of science and in the influences of this knowledge on material and cultural environment. The concrete control which technology exercises, on the whole beneficently, over material surroundings is evidenced so emphatically that it need not be stressed in this talk. The equally significant abstract control which the ways of thought of scientists exercise over all men's ways of thought is little recognized. This second influence of growth and spread of scientific knowledge I shall attempt to sketch with astronomical detachment.

Historians set up other, less important, distinctions between the medieval and the modern, but in a brief discussion arbitrariness can not be avoided. The first modern science (except for elementary branches of mathematics) was seventeenth-century mechanics, which was based by Sir Isaac Newton on the kinematics of Galileo and the astronomy of Kepler. Newton lived from 1642 to 1727. His method of thought still serves as a model for most scientific thinking, although his particular results have been elaborated in detail or superseded in fundamentals. Among all innovators who initiated modernity, Newton's is the outstanding and synthetic name.

The majestic sequence of discoveries of fact and constructions of concept from Ptolemy through Newton has been described often enough. It has been given, you recall, poetic form by Alfred Noyes, in his "Torchbearers." On some later occasion I hope to give it consideration as a case in a novel symbolic logic. Logic and poetry need not be far apart. First, let us refresh our memories with a rapid outline of the work of the early astronomical discoverers.

(2) From Ptolemy through Newton

Claudius Ptolemaeus, in the second century A.D. near Alexandria, summed ancient astronomical lore in a text which, centuries later, was called "The Greatest" by admiring Arabs. Although he understated its size, the earth for Ptolemy was a sphere, and it was unmoving at the center of the universe of planets and stars. He endorsed also the hypothesis that the motions of all celes-

tial bodies be accounted for by combinations of elementary motions which were always uniform and circular, and he showed how observations of the varying angles at which we see celestial objects could thus be explained with accuracy, albeit with some intricacy. Little was added in fourteen hundred years. In 1543 Copernicus published from Poland his revision of the Ptolemaic theory, which made the sun central, although still keeping to representation by uniform circular motions. The idea that the sun might be central, rather than the earth, had been suggested about 250 B.C. by Aristarchus, but Ptolemy's opinion had negatived it throughout the medieval period, during which scholarly interest was concentrated on reasoning by deduction from assumed first principles rather than on reasoning from exhaustive observations made with modern alleged openness of mind. Central tenets of the medieval schools were summed in the supreme writings of Thomas Aquinas, who died, aged about 47, in 1274; he taught that philosophy and theology, reason and revelation, were compatible. For lesser minds, authority falsely borrowed from the theology began to gild with unjustified permanence the principles of long-accepted science.

Tycho Brahe, the great Danish astronomical observer, was born in 1546, the year when democratic Martin Luther died. Tycho redetermined, with precision which had not been reached before, positions of stars and planets. He was exiled in old age from his splendid Baltic island-observatory, and John Kepler in Austria became the fortunate and adequate heir to his manuscripts. Tycho was supreme as an observer, and not especially endowed with genius for speculation. Kepler was not in the least an observer. His passion for seeking harmony in all things resulted in sublimation of Tycho's laborious data into Kepler's three brief rules of planetary motion. His first and second displaced the antique uniform circularity by varying but predictable motion in ellipses; his third arithmetically related the periodic times to the distances of the planets and so introduced into the arbitrary-looking geometrical formalism of Ptolemy and Copernicus a numerical Pythagorean fury, a fresh magical unity. Quantitative relations of similar character in physical science are so familiar now that it requires imagination to sympathize with Kepler's unspoiled delight at this premier discovery. It remained for Newton to resolve Kepler's three laws in "scientific" terms.

Galileo was physicist before he became astronomer; the year, 1564 (when Michelangelo died), was the year of his birth (and Shakespeare's). The Tuscan physicist in 1610 first among men turned a telescope against the stars, and his was the greatest artistry among contemporary astronomers. Because of his lively endorsement of the unorthodox Copernican theory and because of his vigorous exercise of experimental methods in physical science at a time when leaders in affairs academic were sympathetic only with deductive argument *a priori*, Galileo late in life came into conflict with the ecclesiastical powers. He was reprimanded, he was imprisoned mildly, he was deprived of opportunities for teaching. The great school of physical and mathematical research which he might have founded in Italy—where was no lack then of students of ability—with all the technological and economic advantages to his country which would have flowed from such a school, became merely another one of history's might-have-beens. As physicist, Galileo studied the motions of falling bodies; he displaced the old Aristotelian animistic "elements" (fire, air, earth, water) by the modern emphasis on distances and times, and he established arithmetical

rules for predicting uniformly accelerated motions.

In the year when Galileo died, blind and harassed, 1642, Newton was born. Except that Sir Isaac Newton, when elderly, wrote of theology—and, be it noted, theology, although severely attenuated, is still with us—there was nothing medieval in his mind. His English environment was sufficiently modern, in contrast to Galileo's, for him to be nourished in it with acclaim instead of persecution. His mighty dynamics combined in new first principles Kepler's empirical astronomy with Galileo's empirical physics, through enunciation of the three laws of motion and the law of universal gravitation. To Galileo's distance and time, Newton added his own new abstraction, mass, as the third necessary and sufficient "dimension" of mechanics. His compact theory is set forth within a few pages in elementary text-books. It has met every numerical test in the *a priori* elucidation of every observed celestial and terrestrial motion, except when velocities are very great or masses exceedingly minute.

The concern of Kepler, Galileo and Newton with quantitative description of observed facts has been ever since the growing concern, not only of physics but of all scholarship.

(3) The Elements of Modernity: Distance, Time, Mass, Number, Fact, Machine

The slowly developing germ of modernity reached full intensity in Newton; it needed only to spread. It has spread from English Cambridge to both poles; to Pacific depths, to the treacherous air over Everest and to the rarity of the stratosphere; and to thought about life and society and art; shaping mysteries of earth and man to the sharp necessities of *distance, time, mass, number, fact, machine.*

These six terrific idols of the modern mythology may stand on feet of clay; but let us examine first their firm superstructures, their exciting exteriors of porphyry and gold.

Distance: Some of the ancients knew pretty correctly the diameter of the earth, even the distance to the moon, but all much underestimated that of the sun. It was an improved measure of the earth that enabled Newton to verify his hypothesis that the gravitation which curves the moon's orbit is the gravity which makes ripe apples fall. Surveyors chain the fundamental arcs of earth by methods which every surveyor understands; from the baseline of the earth's diameter meticulous astronomers triangulate the distance of the sun. With that radius, 92,900,000 miles, the astronomical unit, now as base, they trigonometrize the nearest stars, hundreds of thousands of those units away. Indirect methods utilizing various properties of stars are called to aid, and the diameter of our stellar system, the wheeling galaxy, intricately is estimated as tens of thousands of times greater yet.

The telescopes plunge deep to other galaxies, and the present maximum observable distance stands in the same ratio to the astronomical unit as that unit, 92,900,000 miles, bears to one tenth of an inch. On the other hand, physicists, studying atomic and electronic phenomena, deal definitively with distances scores of billions smaller than an inch.

Superficial consideration might suggest that what might be called the distance per capita, the individual citizen's share in space, has increased proportionately with civilization's increasing command of space. This is certainly true as regards modern ease of travel, between all latitudes and longitudes on the circled planet. The modern traveler, however, is likely really to experience little of the varied course between his

departures and destinations: rivers, cities, mountains, tides and storms—except the severest—whirl nameless and unnoted past his rapid easy-chair. Impoverished Indians who fished and swam and drank Manhattan's brooks, and watched the stars rise and set in transparent skies, were heirs to vastness denied for renters in the city blocks, who pay scores of dollars per year per cubic yard for airless space to call their own.

Time: The precession of the equinoxes was discovered and underestimated in the second century B.C. by Ptolemy's learned forerunner, Hipparchus. This "great year" of the top-like wavering of the earth's axis occupies about twenty-six thousand years; it was the longest interval of time the ancients dealt with; but of course no one knew then whether even one revolution had been completed. Students of Biblical chronology are said to have arrived at more than two hundred different results for the date of creation, ranging from 7000 to 3500 B.C., the date 4004 B.C. being finally authorized by seventeenth-century Archbishop Usher. Studies of radioactive transformations in minerals indicate now that the earth's crust has been undisturbed by major cataclysm for almost two billion years. This is speculatively taken as the age of the solar system and even of the universe—the so-called "short" time scale in stellar astronomy. The "long" scale is uncertainly greater by a factor of a hundred.

The life of a man comprises about as many seconds as there are years in the undisturbed age of the earth's crust. At time's small end it is hard to fix the temporary present-day limit; physicists speak of radiation-vibrations as short as one trillionth of a second, but what is it that vibrates?

Throughout history the positions of the sun and moon among the stars and their risings and settings have been utilized to regulate days and calendars. As society became more organized, synchronisms and chronologies took more definiteness, not at first in dead numerical terms. We may think of the trumpets of encamped legions of the Caesars as sounding reveille, mess-calls and taps. A few centuries later, monastery life in Europe gently marched to matins, lauds, prime, terce, sext, none, vespers and compline. Galileo's pendulum made accurate clocks a commonplace, and thorough-going time-mindedness began in the western world. To-day factory whistles or railway schedules call workers from and return them to their families; and the more important a man is in affairs the more likely is his alert week to be partitioned off by a squad of critical secretaries in measured quarter-hours; while every shanty in the shortwave radius may possess a broadcast receiving set on which, precisely on the second at 9 P.M., the fragment of a symphony is chopped off in order to introduce the Hottentot Roysterers and their sponsor's importunities.

Mass: Newton's mass is quantity of matter; we have evidence now that it is convertible, and reversibly so, to energy. The mass of the earth was first estimated, with fair accuracy, in 1774, by Maskelyne; it is, in tons, 6,000 billion billion. Extrapolation of the gravitational attraction between two small known laboratory masses at a measured distance gives the best method of determining it. Study by the methods of celestial mechanics of the earth's orbital motion around the sun yields the mass of that attracting center, and this comes out 332,000 times the earth's. The masses of many double stars, which rotate about each other, similarly have been computed; stars roughly duplicate the sun in mass. The mass of the galaxy can be guessed at, and is billions of times the sun's; our galaxy is one of scores of millions within range of existing telescopes.

As a man's mass is to the earth's, so is the earth's to that of the seeable mate-

rial universe—and this infinitesimal ratio is also about equal to the ratio of the mass of the largest organic molecules to the mass of a man; but the mass of an electron or positron is a hundred million times smaller still, and low-frequency photons run smaller again by tens of thousands or millions.

There are ninety-two chemical elements—that many drastically different theoretical primitives of matter—themselves electrically constituted; the myriad combinations of these elements under varied temperatures and pressures are chemistry. All but perhaps two of the ninety-two actually have been found in the earth's accessible skin. Sixty-one have made their presence on the sun known in sunlight, and dozens of these have been identified as well among the farthest stars; and a few in the evanescent clouds which float between the stars. Perhaps additional elements more complex can be formed above the ninety-two. Electronic bombardment at voltages in the millions transforms one element into another of higher or lower atomic weight. An up-to-the-minute "nuclear physics" deals with this bewildering alchemy, making with its isotopic complexities a new chemistry underlying chemistry. Inorganic chemistry merges into mineralogy in the study of crystal structure; and the "organic" chemistry of carbon compounds rises to complexities which seem to vie with those of living bodies; and physiological secretions, in turn, play a large and as yet incompletely appreciated part in conditioning the psychological attributes of life.

Compare the mass and the mass per capita of a savage's equipment with that of a subway-riding New Yorker. For the one the strong arms of his squaw harvested the Indian corn; for the other flying freights and motor trucks converge on metalled roads with refrigerated produce from a dozen states. The trusty twang of the one's bow and arrows outmatched the fleetness of squirrels, rabbits and deer, except during famine winters; the other hopes in his precarious hunting to succeed through the strength and cunning of his factory-chimneys, showcases and filing-cabinets. For the one the easy poles and skins of a teepee, for the other, bricks, concrete and steel, and neon lights pile as high as the dark mountains which shield the old valleys of the Delaware, the Susquehanna and the Shenandoah.

Number: Number has been important during many epochs past—in the medieval, the dark ages, the ancient classical and the old cultures before; but it is only in the modern epoch that the importance of number has become so overshadowing and that the numbers themselves have become so large and well determined. In the first chapter of Genesis, 6 days were required to finish the heavens and the earth and all the host of them. The sixth chapter sets the dimensions of the ark in Noah's resettlement project as 300 by 50 by 30 cubits. Methuselah lived 969 years; is any larger number exactly given in the Bible? The poets of classical science, Aratus and Lucretius, do not make much play with numbers. In all-embracing thirteenth-century Dante, canto follows canto without inclusion of a number larger than 6 or 8. In *Hamlet* is such a passage as

> Full thirty times hath Phoebus's cart gone round
> Neptune's salt wash and Tellus's orbèd ground;
> And thirty dozen moons, with borrowed sheen
> About the world have times twelve thirties been—

Use of poetry as an index to the use of number is a little unfair. Modern poetry is equally innocent of arithmetic—but most of modern poetry may be as yet unwritten.

The evaluation of the ratio of the circumference to the diameter of a circle, "pi," has a longer history than any other numerical constant—except perhaps such astronomical ones as the ratio of the year

to the day, the year to the lunar month. Hipparchus could only discover precession by knowing the ratio of the year to the day as a number of four, almost five, significant places; we know it now to eight, to better than one part in 100 million, and the length of the lunar month to seven. Ptolemy used for "pi" 3.1415; by 500 A.D. the Hindus were using the familiar 3.1416. In 1527 (the invaluable 11th edition of the Encyclopedia Britannica states) two more significant places were established accurately; in 1579 four more; then Gregory, Mercator, Leibniz and Newton established formulae; and, by 1699, the first 72 digits in "pi" had been calculated. With the gluttony characteristic of modernity the computation during the nineteenth century was pushed to 707 places. Any accurate industrious clerk who cares to take the time can go farther. The proof that "pi" is transcendental, that no finite numerical expression for it ever will be found, is of theoretical importance to mathematicians.

Our Arabic numerals date from before the ninth century but were introduced in Europe much later. Following John Napier's invention of logarithms in 1614, the computation of another shadow-number—the mathematicians' "e," the base of the natural logarithms—began. The slogan "greatest good to greatest number" helped to spread political democracy. As celestial mechanics developed, the exact determination of astronomical constants proceeded apace. Recently, in another phase of astronomy, average times between eclipses for short period variable stars have been evaluated to eight precise digits. The first "universal constant" in physics uncovered was the speed of light, which was roughly found by an astronomer, Roemer, in 1675, from the eclipses of Jupiter's satellites; but not accepted until confirmed in 1726 by another astronomer, Bradley, from annual spurious displacements of stars. This tremendous velocity is now known at least to four figures. Followed, much later, determinations of the constant of gravitation, of the masses of atoms, of the charge on an electron and of Planck's constant. The numerical data of spectroscopy are very extensive; a few spectroscopic constants are reliable to eight places and a multitude to seven; careful investigators have given of their lives to make them so. The first pure *ratio* to appear in physics was that of the force of gravitational to the force of electrostatic attraction, which dates from Coulomb in 1785 and which even now is known only to three places. The second, that of the mass of the proton to the mass of the electron, appeared at the end of the last century, and is about 1847. The third involves Planck's curious "h," and is scarcely yet reliable to three significant figures. The most accurate values of chemical atomic weights are to five places. Bulky tables of physical and chemical constants give precise densities, specific heats, electrical conductivities, thermal coefficients and other quantitative characteristics beyond remembering of substances almost countless. Numbers swarm in all the handbooks of engineering. In manufacturing, automobile pistons are fitted with an accuracy of one five-thousandths of an inch. In biological laboratories, with patient statistics through years, genes in fruit-flies are enumerated; in clinics, physicians take blood-pressures and counts of blood-corpuscles.

In a day's newspaper we may scan the 50,000 accurate digits in stock-market reports which symbolize the shifting frenzy of devotees. On a single front page which carried—of all things medieval—an archbishop's rebuke to a king, you might have noted, in the headlines alone: "140,000 loyal Chinese soldiers" —"Germany needs 1,000,000 tons of wheat and 1,000,000 of rye"—"Compromise on 2 accords, text on page 14"—

"Twenty-five miles south of Vienna"—"Painting lost for 40 years"—"Cost of West Coast ship strike put at $311,750,000—"Volume LXXXVI, No. 28,814; second-class matter; December 14, 1936; price two cents in New York City; temperatures yesterday, max. 39, min. 27."

A tremendous tide of number rises around the perplexed modern man; every new number that swells this crest has relationships, tenuous or immediate, to every other number in the flood. Choice at Buenos Aires between 2 accords committing the Americas to joint neutralities conceivably may influence policies of a European nation whose grain reserves are gone, and echoes from those decisions will touch the controverted wharves of San Francisco and ripple to farther shores of Pacific. The number of such internumerical relationships is something like the number of combinations of n things taken m at a time; which, when n is only 1000—the headlines of a month—and m is 4, works out as 40 billion, and as n increases this beats against infinity. Such is the internal and infernal feedback of numbers which interrelate to produce new numbers in number exceeding comprehension.

The second law of thermodynamics avouches, what common sense confirms, that feedbacks such as this almost certainly lead any purely mechanical system away from stability and order. Whatever Newtonian shielding is set—whatever constraints are arranged that rely on physical force—the indefinite regress of numbers reflected in numbers will find some chink in arbitrary conditioning through which to enter and break treasured harmony.

The mathematician knows that confusion feeds naturally upon itself. Only the mystic can match harmony with stronger harmony.

Fact: Now to inspection, without reverence, of the fifth modern idol of the list I gave, the master of them all: his name is Fact. If all the "facts" presented in all the college courses in Princeton, or in any other university equally enlightened, were printed in normal type and strung end to end, the resultant ribbon, when roped around the football field, would form a series of impregnable walls hundreds of yards high. We start, if we like, with the course in "Ancient Architecture," tracing architecture's development from prehistoric beginnings through the historical periods of Egypt, Mesopotamia, Persia, Greece, the Hellenistic East and Rome, down to the fourth century A.D., when Christianity became the dominant factor in architectural evolution. This course gives the student a necessary acquaintance with significant buildings of the past as expressions of civilization, and grounds him also in terminology and in problems of architectural construction. Passing through catalogued A, B, C, "Elements of Economics" also is approached historically to explain the origin and growth of the present economic system. Value, price and distribution are treated; in continuation, economic security is taken as the central problem, and various proposals for increasing social control are examined. When P is reached in the Princeton curriculum, "Abnormal Psychology and Mental Testing" is presented, with the problems of insanity and feeblemindedness, including evaluation of hypnotism and the Freudian theory. Survivors who hardily keep on through S will find in the course about "Structures" an introduction (but only an introduction) to the theory and design of statically determinate beams and trusses; and principles of analytical and applied mechanics are illustrated in the calculation of stresses and in design of building frames, roof trusses and bridges; and minds not over-callow may learn how stresses are determined both by algebraic and by graphical methods, the latter including the Maxwell diagram, funicular

polygon and influence line. At long last, "Invertebrate Zoology" studies the classification, morphology, life-histories, embryology and habits of selected phyla of the invertebrates, with lectures, laboratory work and demonstrations. Results of a diagnostic examination which I inflicted two years ago on good-natured colleagues indicate that not one of the professors concerned with any one of these five courses would be able to pass the undergraduate examinations in any one of the other four.

Increasing plethora of newly described facts flows out in the publications and at the meetings of learned societies in all countries. The academic mills to-day are better equipped for production than for inspection: not every announcement which feeds from the busy assembly-lines is up to standards. Newspapers are devoting increased space to these varying findings, and it is going to be necessary to expect the journalists to be more critical than they have been.

When such an address as Sir Arthur Eddington's at the Harvard Tercentenary last September is front-paged, and a trusting laity is told that this stimulating author's latest mathematical calculations yield for the number of electrons and protons in the universe the figure 136 times 2 raised to the 256th power—surely the accurate reporter will not be indulging in news-column editorializing if he adds: "However, representative physicists from the brilliant audience whom I briefly questioned, emphasized the hypothetical nature of the calculation and stated that no such announcement could at present meet with firm acceptance among scientists, since the very limited relevant facts at our disposal are insufficient to guide the arbitrary mathematics."

Inadequacy of criticism is a predominant failing in modern academic organization. Criticism demands synthesis of knowledge; unless an expert has made himself expert in several widely diverse fields he remains a technician—and has his charm and usefulness; but he has to take most of his thought at second or third hand; and his judgment, even in his own field, is likely to remain immature. Varied expertness is impossible nowadays, most scholars will tell you with satisfaction, because there is so much scholarship that no one mind can compass much.

The driving synthetic responsibilities of civilization do not wait upon such recondite apologies, but are assumed by the well-intentioned ignorant—please number me with those—or by quacks who have been pushed forward to distract attention with their mummeries from a partisan selfishness. In such default of leadership, the native anarchy of events throughout the millenniums has had a way of destroying the very bones of civilizations which have lacked courage and brains to protect themselves from the consequences of their own excessive successes.

Machine: Before I altogether shed astronomical detachment, the sixth stern index which I have chosen for evaluating modernity remains to be considered: let us look at machines, and along with meter-sticks and clocks and balances, I mean to include mental machinery, routines of men's thought and action.

Gunpowder, the magnetic compass, the printing-press, ushered in primitive modernity; but even after Newton the rise of machinery remained for a century very slow. In the late eighteenth and early nineteenth centuries the steam-engine and the use of coal to yield a ubiquitous and reliable power accelerated mechanical development. Enlarging gains from industry and trade continually weakened anachronistic landed feudalism; public and private philanthropy and education flourished as material wealth increased. Growing speed in transportation linked distant areas more and more closely; before 1850 electricity was made to begin its not-even-yet-finished magics of com-

munication and control. Faraday and Joseph Henry were the Tycho-Keplers for electrodynamics, Maxwell became the Newton. Physics remained complacently Newtonian as the nineteenth century closed. Electricity and electromagnetic radiation had been incorporated into dynamics without disturbing underlying metaphysical presuppositions. Boltzmann had emphasized in thermodynamics and Gibbs in statistical mechanics the notion of probability, but its extra-Newtonian implications exercised few thinkers. Darwin, the engineer of Newtonian concepts in the world of life, had imposed his thought—of biological masses colliding and competing in time and space—on a not resistant late mid-century popular philosophy. Karl Marx during those same impersonal years was pushing Newtonianism one phase farther, into the theory of society, and his mechanistic economics was to wait through five decades before exploding across Russia's bicontinental stage. Even in the humanities the protean idea of a mechanistic evolution gave time new emphasis, and the historical approach became favorite.

The gas-engine appeared as the nineteen-hundreds ended; and amid growing speed and speedier amplification in the numbers of almost everything our own new century began. The airplane drove past the automobile; mass-manufacture rushed new devices to meet new wants, which were fostered by staccato advertising among an ever-expanding circle of purchasers—and what these purchasers used for money no economist understands. In psychology the behaviorists asserted that motions are the only activity by which minds are judged. For accomplishing effective motions men formed themselves together more and more into cog-wheels of organized flesh. Wheels meshed with central wheels of higher leverage and controlled in turn peripheral rollers to grind out whatever product implicated mass-motion could achieve.

The Newtonian concept of machine and of mechanical uniformity and law and logic is clear-cut, intolerant, admitting of no exceptions; it is supposed to be impressed from without, by superior nature upon inferior mind; it is alien to personality, and although it has an appearance of rationality this concept may be alien ultimately to reason itself.

Pistol shots at Sarajevo echoed on the telegraph cables. New aggregations started, new revolvings of human wheels. Masses of men and of munitions moved across the face of the earth.

The descriptive words that were used by the popular orators in each nation were honor, fatherland, democracy, courage, loyalty, God; but the modern categories, distance, time, mass, number, brute-fact, Newtonian machines, have no place for what is represented by such words; and the action was the moving of masses of men and munitions. The effective words were: Fix bayonets; Trench-mortars to destroy all wire by zero hour; Stretcher-bearers report to battalion headquarters; Green rocket means lengthen the barrage.

If a waiting cannon somewhere needed two thousand shells to kill a man, lights blazed all night in factories, miners delved as never before, in laboratories scientists sprang to relevant problems, bankers made entries in ledgers, legislators originated committees, freight-cars were shunted, and ships were crammed, and rolling caissons and floating magazines were filled again and again; and in Flanders or in Masuria or in the Apennines, in the North Sea, in the Congo basin, in the Pacific, along the Jordan, on the Marne or among the hills of the Argonne, a man was selected in the lottery of the salvoes.

(4) Contingency: Leibniz, Philosopher of Post-Modernism

Newtonianism's failure at Versailles: Lotteries are a phenomenon extraneous

to strict mechanical science—although in very recent physics, in wave-mechanics, chance phenomena are presented as everywhere fundamental.

A victory in the war was won by the Newtonian action and disintegrated by the subsequent and predictable extra-Newtonian random reaction. At Versailles, would-be engineers of a political world-machine envisaged their problems principally in Newtonian terms of space and time and mass and derivatives of these, in terms of number and of severely defined fact and law. They drew geographical boundaries. They defined terms of years during which vanquished territory should be occupied and monetary indemnities paid. They constructed paper constraints designed to keep opposition from developing an effective counterweight in men and ships and resources. Their legalism regarded law not as natural uniformities but as arbitrary commands laid by superiors upon inferiors.

No epoch is simple: in every age, even the modern, residues of older attitudes and promises of yet-to-be-realized primary points of view, exist. The Divine Comedy is nothing if not medieval, and yet we find Dante endorsing modern empiricism—"From this objection, experiment, which is wont to be the fountain to the streams of your arts, may deliver thee, if ever thou try it." Elsewhere he writes one of the earliest known references to our post-Newtonian theory of probability—"When a game of dice is broken up, he who loses remains sorrowful, repeating the throws, and, saddened, learns." If the same humility were emulated by European diplomats—who seem to have a talent for losing even with loaded dice—international relations to-day would be more propitious.

Not reasoned certainties but extra-rational contingencies disintegrated the Treaty of Versailles and made impotent the League of Nations. The narrow rationality of the framers made the contingencies certain.

Contingency in physics: Eighteenth-century satirical Voltaire had much to do with popularizing Newtonian rationalism as substitute for medieval faith. There is opportunity to-day, with excellent physical backing, for literary assault on a rationalism which fails to recognize the importance of contingency. In physics, Boltzmann and Gibbs, sixty years ago, following Carnot's earlier lead in thermodynamics, broke into new territory quite outside Newton's contemplation, when they began concretion of the mathematical theory of probability. The kinetic theory of gases is our classical example; Maxwell contributed to it: the motion of an air-molecule between and during collisions (neglecting subtleties of very recent wave-mechanics) is in detail Newtonian; but the billions of collisions per second of each of the nine hundred billion-billion molecules in a cubic inch of air obviously can not be followed so, and the indefinitely diverse courses of the mutually disturbed molecules raise problems of a new order, which are met by introduction of the notion of probability.

The meaning of probability long has been subject of disagreement among the philosophically-disposed. Unquestionably, probability is no derivative of Newton's distance, time and mass. It can be measured by number, but only after an arbitrary convention is adopted as to what number shall stand for certainty; intrinsically it has no more to do with number than has space or time. Puzzling paradoxes are met if attempt is made to include probability in the domain of fact and law as Newtonians understand these. My own opinion is that probability represents an incidence in physics of the philosophical principle of "sufficient reason."

Origin of mathematical theory of probability: The principle of sufficient

reason was made by Leibniz, Newton's contemporary and consummate rival, a cornerstone of logic, but Leibniz's logic has had as yet no detailed development. When two dice are thrown, what is meant by saying that the dice and the throwing are fair? We mean that of the six times six possible combinations no one differs in likelihood from any other—double one, or "snake-eyes"; one, two; two, one; double two; one, three; and the rest. That is to say, we have *in*sufficient reason for supposing that at the next throw a particularly assigned combination will appear. The subsequent mathematics is mere enumeration of combinations.

The origin of the mathematical theory of probability is a curious passage in the evolution of ideas. According to references compiled in Todhunter's "History," Kepler and Galileo exhibited a little interest in problems of chance and combination; but Galileo's contemporary, Descartes, mathematician and philosopher, gave the subject no attention. Leibniz was definitely sympathetic toward it, but did not contribute much to the mathematics. Apparently Newton completely neglected theory of probability, although elegant mathematical theorems of his yielded important by-products for later application. The mathematical theory was founded, essentially, in correspondence which passed between Pascal and Fermat in the middle seventeenth century when Newton was a boy in his teens and Leibniz was four years younger. It is hard to explain the lapse of several score years which followed before problems of chance began to be studied again; apparently the mathematical atmosphere during the interval was too severely rational for chance to flourish.

First application of the theory to problems of physical science related to reduction of the effect of errors of observation by averaging. First work in this important field was in 1757 by Thomas Simpson, and although he was professor in a military academy his study dealt with measures in observational astronomy, not with dispersion of shots around a target.

The marine underwriters who during the late sixteen hundreds fell into the habit of assembling in Lloyd's coffee-house to ply their trade in risks did not wait for the tardy actuarial mathematics which helped to foster in the nineteen-hundreds a vast development in all kinds of insurance. This development is a unique characteristic of our times. To-day it is desire of average citizens for protection against risk of unemployment that outruns mathematics.

Many business men who even to-day are far from being masters of the mathematical theory of statistics rely nevertheless for their profits upon the recurrence of very unusual wants, a recurrence which can bring steady flows of customers to their doors or mailboxes only by virtue of the statistical steadiness which large circles of potential customers ensure. One such example is the enterprise of manufacturing glass eyes. The steadiness of rare circumstance which large numbers guarantee is an obvious notable factor in the continuing growth of cities and of all sorts of highly specialized metropolitan organizations.

Philosophy of Leibniz as possible influence on modernity's successor epoch: The fundamental ideas of modernity, it seems to me, reached full stature in Newton. Mathematical study of contingency is chiefly post-Newtonian, and its nineteenth-century applications in physics are definitely extra-Newtonian. The conclusion of the indicated syllogism is that the germ of modernity's successor-epoch, Post-Modernity, is already forming.

Thoroughgoing recognition of the importance of contingency leads to results far more important than the mere mathematical discussion of probability, more

important even than the grab-bag exhibition of equally valued trivial experiences and random petty images which is coming to constitute favored and not unpleasant technique in literature, art, ethics, education and politics.

To the acute mind aware of *contingency,* fact itself no longer is presented with the sharp distinctness which it has for Descartes—who, with Galileo, was source of Newton's own philosophy. Involved with every fact in the text-books is an indefinite regression of other facts which are implied and assumed in statement of the first. The nearer is a fact to the temporary limits of knowledge, the more implicated becomes this regression and the more blurred ought to be statement of the fact.

Bridgman of Harvard recently has emphasized this conclusion, but his post-modern position has as yet made small impression; nor would he be sympathetic, necessarily, with my further comments.

To Leibniz—whose philosophy is very different from that of his more successful contemporary, Newton—truth is necessarily just such a varying blur as Bridgman describes in "The Logic of Modern Physics": ranging from clearer and more distinct to clouded and obscure; never utterly sharp, never wholly blurred. For Leibniz the minds which reflect truth form a similar hierarchy.

I hope you have been lured out now to the frontiers of knowledge—of philosophical knowledge at that, which is by all odds the vaguest. Awareness of contingency is intimately related also to awareness of the possibility of *control:* brute-facts lose their implacability for a society in which free precise scientific description of conditions is followed by courageous invention and energetic enterprising.

To society, to minds at this level, nature shows a different aspect than to Newtonians: distance, time, mass, lose significance, except as abstractions sometimes useful; number is replaced by intensity; all apparently isolated facts merge, I think, into what Lovejoy in just-published lectures names "the great chain of being," the postulated hierarchy of all things, which has stimulated minds in every epoch before the modern. Dante describes it thus—"All things whatsoever have order among themselves. . . . In the order of which I speak all natures are arranged by diverse lots more or less near to their source." This is exactly the standpoint of Leibniz; who elaborated the position further than his predecessors: in any given fact all other facts are implicated, more or less distinctly, but without destroying its independence. The universe for him is constituted of *monads;* and each monad reflects the universe, with clarity proportionate to its own degree in the "chain." What for Newtonians is arbitrary law is replaced to Leibniz by inner *harmony* which the monads share, according to their degree, and which is their only interrelation.

A corollary of this Leibnizian philosophical postulate is that all the subjects which scholars study can be made, notwithstanding their unique content, to exhibit more or less distinctly a common logical pattern. The search for thorough-going analogies of form becomes then a notable method of research, supplementing our intolerant modern empirical testing.

To Leibniz, not atoms bobbing through space in time's thin stream and not inhumane facts related together only quantitatively by illogical laws of nature, but monads are the Real. A monad is embryonic personality, its quantity perhaps is clarity as its energy is sympathy.

Leibniz was Newton's fertile peer in pure mathematics, his scarcely recognized and at the time unsuccessful opponent in the interpretation of physics, his great superior in systematic philosophy: whose ubiquitous continental genius

was participating in every linkage from medieval to modern, when Newton, close islanded in Cambridge and London, was calculating unsurpassed quantitative agreements, reforming English coinage and grinding telescope mirrors. Newton acted out his logic in his study and his laboratory and never wrote of it; Leibniz wrote of his, and it was too subtle for effectiveness in that raw time. Newton's logic has been the logic of our age; but modernity is decadent.

Leibniz's long-disregarded logic is a challenge to every competent scholar who is willing, in order to advance his special field, to risk contributing also toward broad interests of society. If it can be proved that exact and apparently widely separated disciplines—such as thermodynamics and jurisprudence—can be set forth to some extent in a common symbolism, then specialism becomes path to universality. Resultant intensification of learning's humaneness will end modernity.

If it be objected that this suggested philosophy for post-modernity is too closely linked with pre-modernity, which is to say, medievalism, no one can assert that philosophy-of-history—the great dynamics which has been imagined, perhaps too romantically, as describing the succession of society's primary passions and motions—is a subject in which reliability exists. For what the over-simplified analogy may be worth, however, I would reply that recognized first stirrings of our own epoch, Post-Medievalism, came with the "revival of learning" when scholarship gained fresh vigor from fresh contact with problems which had been neglected since the close of the ancient or pre-medieval period.

Decadence of Modernity: Newton died five years before George Washington was born; he ground the first reflecting telescope, and these mirrored the difficult stars scarcely more distinctly than Newton's mind reflected modern triumphs of technology. Galileo's condemnation, Kepler's discovery of numerical harmony, Tycho Brahe's exile for his shameful interest in astronomical observation are three centuries back and more. It has been long since science began as young revolutionary in a hostile world. Space, time, matter, number, fact, mechanical law—these we sought and these we have been given; but Tycho's poetry, Kepler's free imagination, Galileo's daring independence—these remain uncommon.

It is in the nature of a boom to overshoot just valuations, and success of Newtonian thought in relation to things material is as splendid a boom as history records. There are more workers in science by far than ever before; there is no sign of approaching lack of productivity among them—if productivity be judged by their own specialized standards. I dare say that theologians three centuries ago who tried to stamp out radical empiricism considered that their own old dialectic remained satisfactorily productive, for within their bounds of recognized orthodoxy permissible disagreements existed in detail and served for endless delightful arguments among the brotherhoods. Such argumentation had passed, however, its marginal utility as regards its human value.

On the other hand, no competent student of natural science, I think, however competent or incompetent he may be as critic of civilizations, will support the idea that scientific investigation should presently cease or slow down, that there should be now a moratorium on science. It is not science but Newtonianism that is under indictment for many of the unpleasantnesses of our times.

(5) Post-War Technology and Physics

The first world war and the following booms and depressions in business were only incidents in the continuing drama of onrushing science and technology.

After 1914 the speed of airplanes trebled, and their loads and non-stop range doubled and doubled again. Buildings and ships grew bigger and bigger, along with losses of stockholders. Automobiles were fabricated in number beyond belief, as this American mass-industry followed the lead of Henry Ford, who had been first manufacturer in the world to pose his problem purely in Newtonian terms of the speeding assembly line. Photography, which already had begun to move, projecting time and space in melodramatic masses of light and shade, moved more gracefully and expensively to nightly audiences of increasing scores of millions, and no longer in dumb-show as vacuum-tubes were perfected and electricity became sound's docile slave. Radio put into every kitchen the authentic voices of kings. Mountain-ranges were stripped of remaining forests in order to satiate printing-presses.

Of these externally productive years a future historian may say, "It speaks a marvel for the adaptability of man that insight should not have been even less effective than it was, so burdened and so isolated did minds become in this inchoate mass of literacy."

Books were publicly burned and their authors sent to internment-camps. Churches and cathedrals were converted to secular uses.

In physics the genius of Einstein adapted differential geometry of many dimensions to fundamental description of dynamics; already in 1905 he had exhibited time as a sort of space; and in 1915 he resolved the distinction between inertial and gravitational mass—which always had puzzled the Newtonians—making mass also a property, a warping, of his complicated space. This "general relativity" was astronomically verified, with justified publicity. Pure mathematicians had been operating, for the most part, in a vacuum, almost ever since calculus, which is very generally applicable, had been invented by Newton and Leibniz; here in relativity are fresh applications, although of far less practical significance. Planck in 1901 and Bohr in 1913 had led, with less acclaim, another successful, and to physicists more interesting, departure from Newtonian methods in dynamics, in the theory of radiation and atomic structure. In this movement also Einstein had an important share; during the nineteen-twenties it was the chief activity in physics; Heisenberg and Schrödinger and other theoreticians contributed powerfully, and a new subdivision, "wave-mechanics," was founded. In this discipline probability seems to play a chief rôle, and scant shrift is granted "classical" ideas of Newton and Maxwell. Overtures have been made with a view to reconciling wave-mechanics with relativity, without result as yet. Experimental interest in the laboratories now has shifted center of intensity to "nuclear physics," with growing refinement in the high-vacuum and high-potential engineering.

RIVER AND SEA

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My first direct acquaintance with river problems occurred in 1912 when I began my investigations of plankton (floating organisms) production in the San Joaquin River in California. In 1917 my activities in plankton research were transferred to the Pacific Ocean. In succeeding years I have wished again and again that I could repeat my river investigations under the guidance of my wider experience and knowledge. In connection with the thoughts leading to such wishes I have tried to imagine some of the results which I might hope to get. I have also given much thought to problems of river plankton as related to problems of ocean plankton and to the influences exerted by one upon the other. As a result I feel that some of the many interesting and important features in these groups of natural phenomena deserve attention and discussion.

Of course, we all know that there is a positive continuity in the existence of water on the earth and in the air, but it is not likely that any of us remember that point very frequently or that we think about it very definitely. Perhaps it is not necessary that we should, unless we believe it to be entertaining or profitable to examine natural conditions from every view-point. However, I am tempted to try to discuss water in a way slightly different from ordinary.

In the first place, I wish to emphasize the fact that water tends to be absorbed by the air. We are so accustomed to seeing water flowing in a liquid stream that it is difficult for us to appreciate the fundamental importance of air in its transportation. Under the simplest conditions occurring in nature a mass of air lifts a load of water from the sea (or other large body), carries it a short distance vertically or horizontally and drops a part of it. But, with the rarest exceptions, it is only water that is transported by air in this way. When the load of water is lifted all dissolved and suspended substances are left behind. Momentarily, at least, the surface of the ocean at the loading point becomes slightly more dense because of the solid residues not taken. If the load is dropped again on the ocean a reverse change takes place momentarily and the surface density is lessened.

In cases almost as simple the load of water taken from the sea is carried over land until proper conditions lead to its loss, but the results are far different. Most evidently, the sea has incurred an increase of solids as compared with its fluid mass, a burden from which it can get no relief except as it is able to drop parts of its load. Less evident, but far more important, are the results on land. There the water released from the air may be involved in several different processes of change. Most notably, it may be used by organisms to sustain life, it may be absorbed by solids which it helps to disintegrate, it may dissolve substances from the surfaces of solids, it may absorb gases, it may carry many kinds of substances in suspension, it may push objects that it can not carry, it may collect into pools or larger bodies, or it may be quickly reabsorbed by the air and carried to some other place favorable for unloading.

Immediately, or indefinitely later, any particular air load of water contributes to the formation of a stream after it is discharged over land. Most of it may be again absorbed by air before a stream of considerable size is formed (in deserts even large streams may disappear in this way), but the remainder flows on toward a final union with the sea. Before the

time of this union, perhaps throughout its journey after the time of discharge from the air, this remainder has been carrying burdens not always the same either in amount or characteristics. Joined with it in the river are remainders of other air loads, each with its own history of travel and of burdens accumulated or changed or released. In any case, most of the water flowing into the sea as a river has had a history so complex as to almost surpass our imagination.

Sooner or later after meeting the ocean river water loses its stream identity. It loses parts of the burdens peculiar to it and it acquires other burdens peculiar to sea water until the union is complete and it has become again an indistinguishable part of the sea. Under favorable conditions some large rivers retain their identity as streams of fresh water for many miles after flowing into the ocean. Others may have the union so far advanced while flowing through bays or other coastal indentations that there is no distinction between sea water and river water at the final entrance into the sea. In some regions rivers are constantly contributing to the sea. In others there may be intervals of months or years between times of flow of fresh water into the sea from local rivers. In Southern California a number of rivers are dry for months of nearly every year.

A strongly flowing stream carries much suspended material which may be deposited as a delta or alluvial fan on land if the lower reaches of the bed traverse level or nearly level territory. According to conditions this delta may be extended indefinitely under the sea or a branch of the sea. In any case the less buoyant particles will be deposited first, on land in some cases, near the shore in others. In definite progression according to lack of buoyancy other particles will be deposited in successive distances from shore until all or nearly all sedimentary material has been lost. Thus the river water loses one of its distinctive burdens very rapidly in most cases.

Probably the simplest form of such conditions is shown by the runoff of temporary streamlets from the hills at the Scripps Institution of Oceanography at La Jolla, California, after heavy rainfall. Inside the breakers the water is distinctly muddy in appearance, not only because of the size of the suspended particles but also because of their relatively high abundance. Beyond the breakers the color is somewhat lighter and the fluid looks thinner because the heaviest particles have been deposited and because the muddy stream water has been diluted with sea water through thorough mixing in the breakers. Further seaward a gradual reduction in muddy color occurs until it may be entirely lost at a distance of a mile or less. As the last trace of eroded material disappears from sight one may be tempted to assume that significant influence of the streamlets has reached its limit, that fresh water has become sea water and that its contributions to sea water have been completed.

I believe that this assumption is untenable. Admitting that soil particles have been scattered so widely by dilution that their presence is not visible, there is still the probability that those of more nearly buoyant form or composition may be supported by water movements until they are many miles away from their point of entrance into the sea. Some of them may go into complete solution or decomposition without ever sinking to any notable extent in sea water. Furthermore, it may be supposed that a particle of fresh water may merge into sea water without losing its physical identity. By losing some of its fresh water load and taking on some sea water load it may change its general relationships, but it need not be decomposed in those processes and it may retain some items of its fresh-water load. For example, if the particle of fresh water carries a trace of iodine too small for satu-

ration it may retain that item indefinitely. In that case, it may contribute that much iodine influence to accompany sea water in some area far from its source which has been reached through the vagaries of oceanic circulation. If such extensions of influence be possible from temporary streamlets they are far more nearly possible from the flow of rivers into the sea.

To the student of life in the sea the problems of the influence of rivers and other inflowing streams seem very intricate and difficult but of the highest importance. Some years ago Gran and other observers of marine plankton plants favored the idea that runoff from land contributed substantial amounts of nutritional substances to the sustenance of plants in the sea. More recently, apparently, Gran has abandoned this view, although he has shown experimentally that added traces of certain substances such as iron have much to do with invigorating or accelerating processes of growth and reproduction in marine plants. Still, I do not know of any direct proof that even the nutritional contribution of runoff is negligible. I do not believe it to be so, although I agree that nutritional results may not be direct and immediate. A soil particle, organic or inorganic, useless to plankton plants as it enters the sea at the shore, may be highly useful to them after a period of disintegration or decomposition in sea water with or without the action of marine organisms. It is also true that some particles may not be useful to plankton plants without the presence of activating substances or other complementary conditions.

My indulgence in the foregoing elementary discussion has been due to my desire to show that my view of the characteristics of rivers and of the phenomena of their existence is considerably different from that of most students of river waters. As an oceanographer, not only am I more than ordinarily interested in rivers as individual streams but also in the "system" peculiar to each river, in the whole group of eroding and transporting waters moving to the sea. My own river studies were made in only two localities on a single river, and the results seem pitifully inadequate in consideration of what I would like to know about that river as a whole. One outstanding point in my memory of my observations is that the conditions of plankton production (and of the river in relation to them) were radically different at Stockton, California, and at Fresno, California. And I know from cursory inspection of other sections that each of them must have been also widely different. When I speak of the San Joaquin River I visualize the section at Stockton, with which I was most acquainted, but I know that the visualization does not correctly represent that river as a river. This is especially true when I think of the relationships of this river to the sea, a relationship complicated by the fact that other bodies of water intervene between them. But, ignoring this matter of mergence with other waters before reaching the ocean, I wish to mention a few ideas relating to the river alone.

So far as the observations near Stockton were concerned it appeared that in the flood waters of summer little, if any, plankton existed. A little later, in the relatively sluggish waters of late summer and early fall, it was just as evident that abundance of plankton was very high. Considering plankton production alone in the lower reaches of the river, it is surely certain that there were marked differences in the contributions made by it to the sea at high water and low water stages. Can we rightly avoid consideration of the influences of these contributions with the excuse that all traces of their identity are lost in the long passage through the bay to the ocean? If we can not rightly do so, we should admit that conditions in any part of the San Joaquin

River system have fundamental interest for students of the sea because any part may be the source of some contribution which helps to explain some particular observed condition in the sea.

Viewing the San Joaquin River system as a whole one may imagine that a particle of iodine (or similar substance) captured by a particle of water in the high Sierra may be carried without change down the mountain slopes, along the valley floor and through San Francisco Bay to the ocean. Perhaps it is less likely that a particle of calcium or iron may be carried so far without change. Some plant may remove it here, some animal use it there, and it may finally reach the sea as a component of some organic waste. Surely similar statements may be made concerning the possible river history of limitless numbers of different kinds of materials. And the numbers of changes and kinds of changes in these materials will have much to do with the character of the influence of any one of them or of all of them after reaching the ocean.

Although a marine investigator might not be always aided in his understanding of conditions observed in the sea by having a knowledge of occurrences in all parts of a river system, he would be interested if it could be shown that a series of phenomena in upper reaches of the river had traceable influence on the contributions finally made by the river to the sea. If a shift in these phenomena in the high mountains in a certain year leads to great productivity of plankton in the lower river and so either reduces or augments the contributions favorable to plankton production in the sea he may be directly and positively interested in them. If a migrating stream bed of some tributary of the river reaches a new deposit of salt or other soluble substance, it may have enough influence on both river and sea to change the amount and character of plankton production in certain localities in a particular year. A river change of this kind would be just as interesting to a marine biologist as to a specialist on river studies.

Observations on phytoplankton in the eastern Pacific, made by the Scripps Institution of Oceanography, have shown positively that in the whole range from Alaska to Peru, from frigid to tropic waters, there are localities which are heavily productive and other localities which are poorly productive of phytoplankton. No direct relation of river runoff to the showing of either type of locality has been found, as yet, but it surely is possible that conditions of land drainage account for at least some of these phenomena. In one locality some stimulating or accelerating substance may be acquired from river water in a way to increase production. In another locality such material may not only be lacking, but enough of some inhibiting substance may be present to limit production.

In either case the marine biologist might know more about production problems and many other problems of the sea if reliable information concerning river systems as wholes could be found. It is not enough to know that the water at the mouth of the river contains so much calcium, so much magnesium, so much potassium, so much sodium and other substances easily recognized. So far as marine organisms are concerned, it may be more important to know the availability of less abundant elements or compounds or of an indefinite number of organic compounds. Lacking opportunity to conduct chemical analyses in either number or refinement sufficient to show these things, something of the influential differences in river waters might be surmised through knowing river history and river characteristics in all its parts.

At any rate, it is my belief that rivers have enough influence upon the sea to deserve more attention than they have received, particularly in relation to biological phenomena of the sea.

THE CONTROL OF RAGING WATERS

By Dr. A. F. WOODS

DIRECTOR OF THE GRADUATE SCHOOL, U. S. DEPARTMENT OF AGRICULTURE

A CENSUS has never been taken to find out why people select a river bottom as a place to live when higher ground is available. But we know that flowing waters have an unmistakable appeal to those who live in contact with them.

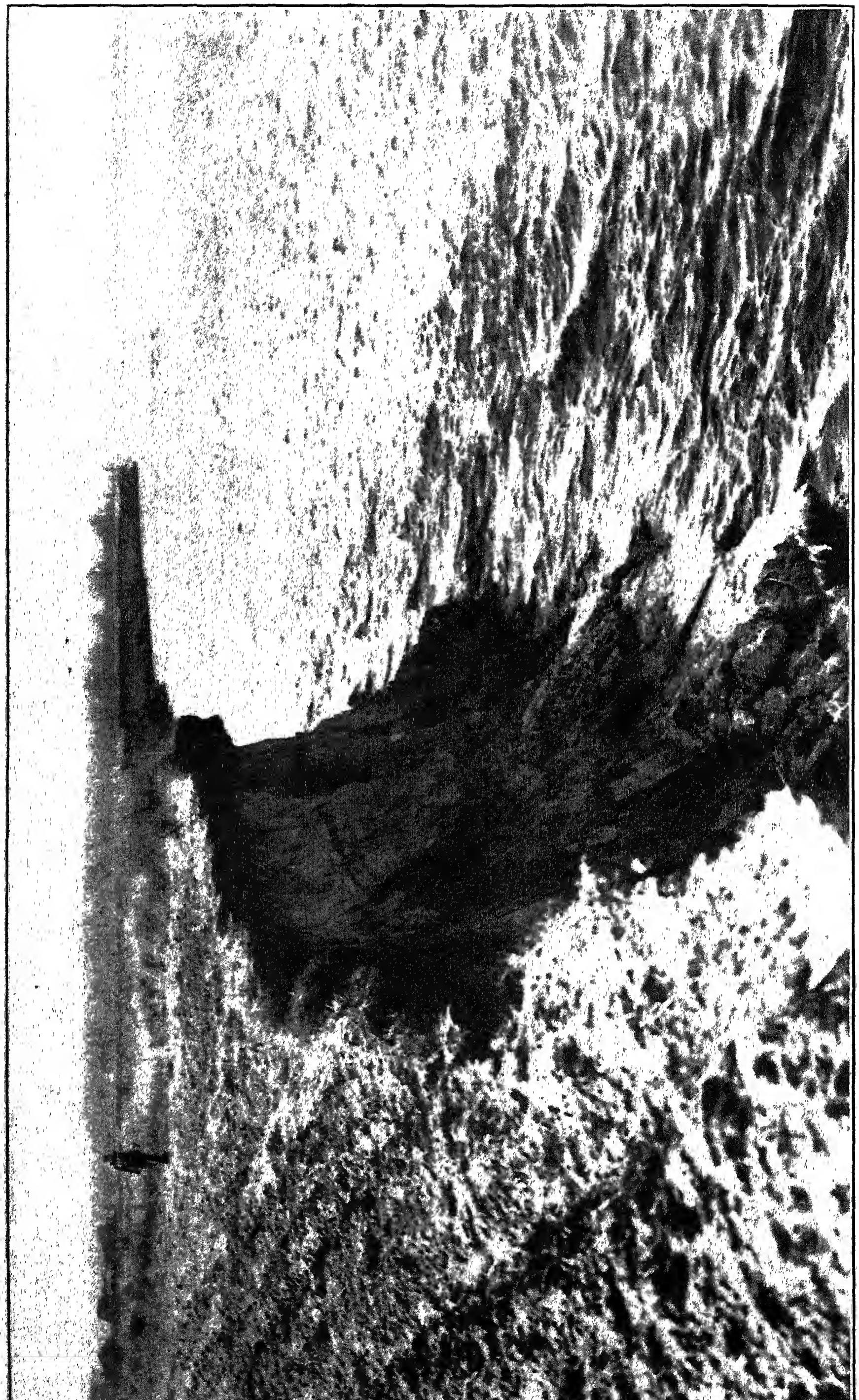
It is a kind of hypnotic effect, a dream-like projection of self to the distant places to which the waters are flowing. These dreams bring enchantment to the Huckleberry Finns who dwell by the river.

There is always something going on by the river; fishing, hunting, boating, and when the storms come or the winter snows suddenly melt, there is the hurried preparation for floods and, if necessary, a temporary move to higher land. All this furnishes some excitement.

When the floods are more or less local in their origin the river-wise usually know when to move to higher land. But when the waters come from large and distant areas, local calculations fail. Agencies in touch with the larger area must furnish the information necessary to enable the isolated communities to protect themselves. Only the state or federal government can do this.

In our great drainage basins, like the Ohio Valley, the Missouri Valley and the Mississippi Valley, in the earlier days before the forests were removed from the tributary waters and before the land was broken into farms and the natural vegetation cover destroyed, the river channels were deeper and more of the water was absorbed by the ground. The flow in the streams and rivers was more uniform and floods less common and less destructive.

THE RIVER MINES UNDER THE BANK AND CUTS IT OUT.



BANK EROSION ON THE MISSOURI RIVER.

UNTIL THE PROTECTION WORK WAS PUT IN BY THE GOVERNMENT THE ANNUAL LOSS WAS MORE THAN 100,000 ACRES OF THIS FINE FARM LAND.

The river-wise could plan with greater certainty.

Inviting the Floods

For nearly a century the people inhabiting these great river basins have been engaged in a program of cutting down the forests, breaking up the prairies, draining the swamps and wet lands. Water has been treated as something to get rid of in the quickest way possible. The result is that the richest top-soils have been washed into the streams and rivers and carried on to enrich other areas or on out to sea. The heavier materials gradually fill the river bed, thus reducing its carrying power and increasing the danger of overflow. When torrential rains come the sand and gravel are carried out to cover and destroy fertile lands.

The worst conditions on a large scale are found in the lower Mississippi, Ohio and Missouri Valleys and tributaries south. Below the confluence of the Ohio and Missouri the areas covered by floods have been large.

In the Early Days

But in the early days before flood protection programs were developed, the water spread out over large areas and did little permanent damage. I have frequently seen small creeks tributary to the Missouri, as far north as Omaha and 50 miles from the Missouri, become in a few hours a mile wide with back water from the Missouri. This might last for a few hours or sometimes several days or weeks. The top-soil was more or less washed from cultivated lands, but most of the area being in native wild prairie grasses, the soil was not disturbed. Nearer the Missouri more sediment was deposited wherever the water was retarded in its flow, but this sediment was largely rich soil that added to the fertility. The river bottom soils were then and are now very rich with a deep deposition of water-carried material. Much of the time these soils can be cultivated. They produce large yields of corn, wheat and hay.

When the Floods Come

But when the floods come the raging waters may destroy everything. Even though the waters may be confined within the banks, the banks themselves may be washed away by the rushing waters. New channels are formed, and what was once fine farmland disappears in the river. Buildings, fences, roadbeds and railroad bridge abutments may be destroyed as the rushing waters eat the bank away. The action is so rapid that one watching may see great chunks of earth weighing many tons topple into the water every few minutes.

Discovery of a New Plan of Control

Many kinds of schemes have been tried to prevent this bank erosion, but nothing was found permanently successful until a plan was devised by a man who owned some of these riverside farms along the Missouri and had watched them float away down the river.

The man was Mark W. Woods, of Lincoln, Nebraska. The story is interesting and is worth telling, as it has now become standard engineering practice where similar problems of bank protection are involved. As already suggested, the objection to the old methods was their failure to withstand the digging power of heavy floods, therefore requiring frequent replacement. The expense involved was prohibitive, especially in the case of the small landholder.

Mark was fond of hunting. Each year when the season came he spent some time on the lower Platte, which is a river of quicksand with many shallow pools furnishing food for ducks and geese. On the particular occasion to which I refer he was on a hunting trip with General

—*Courtesy Field and Stream*

GENERAL CHARLES G. DAWES WITH MARK W. WOODS COMING IN FROM A DUCK-HUNT.

Pershing and the superintendent of the Burlington Railroad. They were hunting near where the Burlington Railroad was constructing a bridge across the Platte. It is well known to engineers that it is very difficult to secure adequate foundations in quicksand. The Burlington superintendent invited General Pershing and Mark to inspect the bridge project. The work of placing foundations appeared to be proceeding with less trouble then under ordinary favorable conditions. Great concrete piles weighing many tons and 75 feet long were placed by a great crane where the engineer desired to sink them and in a few minutes they were out of sight below the bottom of the river. To any one familiar with driving piles in quicksand this was an eye-opener. Mark was interested at once and, finding that the chief construction engineer, Mr. Bignall, was a next-door neighbor and friend, he asked for an explanation. Mr. Bignall explained that he was using a specially constructed pile which he had devised and patented. It consisted of reinforced concrete, with a large iron pipe extending lengthwise through the center with an attachment for a pressure pump at the upper end and a steel cutting shoe at the lower end, the outlet of the pipe at the lower end extending through the center of the shoe so that the water under pressure could dig the hole for the pile to occupy. Side off-shoots were provided on each side about two feet apart to keep the sides free from sand pressure. As long as the pump pressure, about 150 pounds to the square inch, was maintained, the pile

could be churned up and down to chop through hard pan or soft rock, until it reached the depth desired; then the pump pressure was removed, the sand settled in and the pile was in place permanently. The piles went down like pencils in cheese.

Mark thought right away, "Here is a method of permanent anchorage that might be adapted to riverbank erosion control."

A New Use for the Bignall Pile

He ascertained that the pile was being used only for bridge construction, by the Burlington, where ordinary methods could not be used. The Burlington paid a small royalty to their engineer for the use of his patent pile. It did not take Mark long to arrange for the exclusive use of the pile for other purposes on a royalty basis. He confided his plans to General Pershing, who was interested and asked to be kept advised as to how the plan worked out. Mark then called upon the government engineers in charge of work on the Missouri. He asked for permission to place brush retards in the river where the former line of his property had been, with the idea of causing sedimentation of the mud and the building back and further protection of his land. The engineers were very skeptical of the success of the plan. They said: "You will spend a lot of money. The plan may work for a while but when a big flood comes all your work will be lost."

Mark insisted that he wanted to give it a trial and the engineers consented. He rigged up a flat boat with a heavy crane and the other necessary equipment. He then cut cottonwood trees, which were plentiful in the bottom lands and tied them in large bunches with galvanized cable and hauled them by tractor

—*Courtesy Field and Stream*

GENERAL JOHN J. PERSHING AFTER A DUCK-HUNT (LEFT).

and anchored them to the concrete piles sunk by the method described, far below the digging power of the river. These tree retards were placed in lines extending from the river bank to the former property line. The retards were forced down practically to the bottom with the tops extending up to catch flood waters.

They were placed at intervals of a few hundred feet, forcing the currents of the river into the main channel. The slowing down of the water caused sediment deposition. In a few weeks there was a mud flat where before water had been flowing.

THE CONSTRUCTION OF THE BIGNALL PILE.
THE LOWER END MAY BE FITTED WITH A V-SHAPED STEEL CUTTING SHOE IF DESIRED.

Floods Rebuild the Land

Each flood built the fill higher. Fortunately for this test maximum flood periods developed during the year, each adding its load of mud. By the time of the next hunting season the lost land was practically recovered and General Pershing and the Burlington superintendent were invited to inspect the project. They were greatly impressed, because much of the government work on the river had been washed out by the same floods that had only improved this project. General Pershing invited army engineers from Washington and from stations on the Missouri and Mississippi Rivers to inspect the project. The engineers were impressed but not convinced. They knew of some situations where they felt that the plan would not work. One in particular was where a great whirlpool was caused by a side current of the river striking a railroad bridge foundation abutment. It was digging a deep hole near the bridge foundations. Trainloads of rock and even old steel cars had been dumped into the hole, but without avail. It looked as if the bridge were doomed.

The engineers said to Mark, "If you can stop that whirlpool and fill up that hole there will be plenty of work for you to do in controlling Old Man River."

It looked like a hopeless job, but Mark studied the trend of the river, found where a few retards might deflect the main current into a channel away from the abutment. He placed these retards. The current changed, as he had hoped it would. The whirlpool was eliminated, the hole was filled by the river itself, and the bridge was saved.

A new method of permanent bank protection was thus demonstrated which was inexpensive compared with the results achieved and capable of very wide adaptation. A type of pile was developed for making solid concrete dike facing. One side has a V-shaped notch and the other an inverted V to fit the opening. The piles are sunk side by side thus locked

together. The work is rapid and permanent and comparatively inexpensive, considering that other types of protection are not permanent. Many miles of dikes on the lower Mississippi and Gulf Coast are now thus protected.

When the water is held within bounds it digs its own channel deeper, aiding navigation and facilitating run-off.

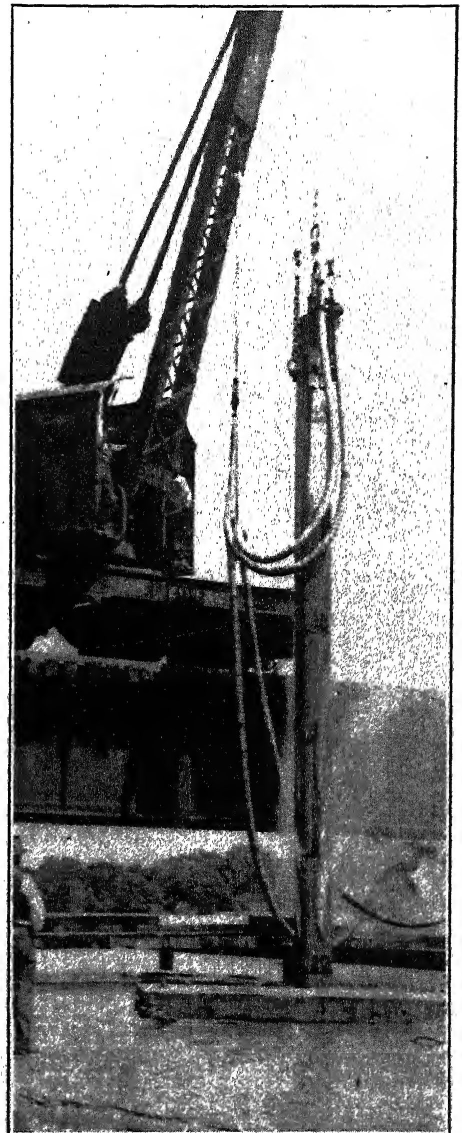
A National Program

The great erosion control programs of soil conservation reaching back to the farms, forests, foothills and mountains are now recognized as the first line of attack on the flood control problem. Bank and dike protection with reservoirs, lakes and spillways and deepened channels are the final line of defense against raging waters.

The scientific aspects of flood control and soil and water conservation are described in a clear and interesting way in three papers presented at the Rochester meeting of the American Association for the Advancement of Science in June, 1936.[1] A careful reading of these papers will make it clear that the great programs of conservation of soil and water are fundamental to the continuance of our civilization. Great and prolonged drouths and raging floods make us awake from our slumbers and study causes and devise methods of protection.

These studies have shown that while losses almost beyond computation have taken place in a few generations, we can by wise planning and vigorous action in a considerable measure restore part of what we have lost.

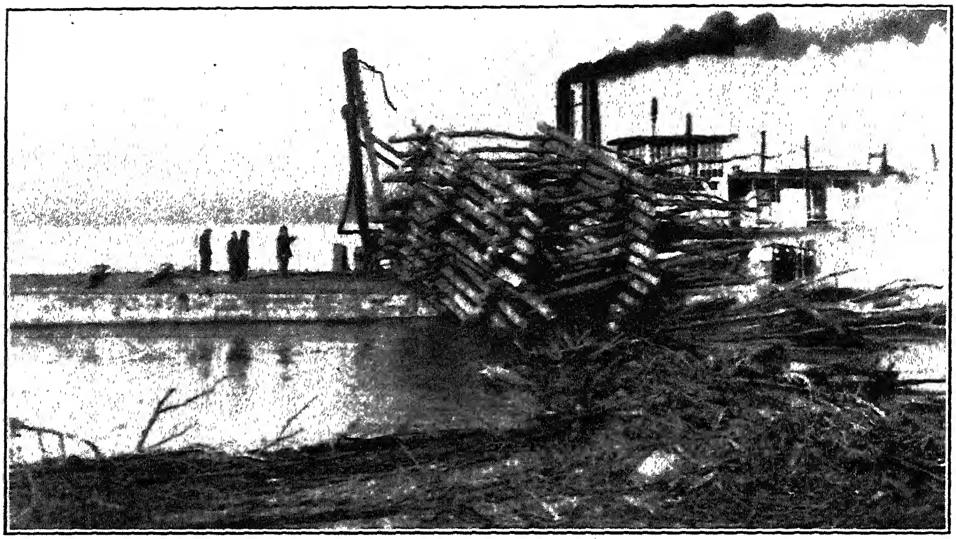
We can restore the underground water reserves by controlling run-off and in so doing prevent soil erosion and loss of fertility. The stream beds are not filled



THE ORIGINAL BIGNALL PILE

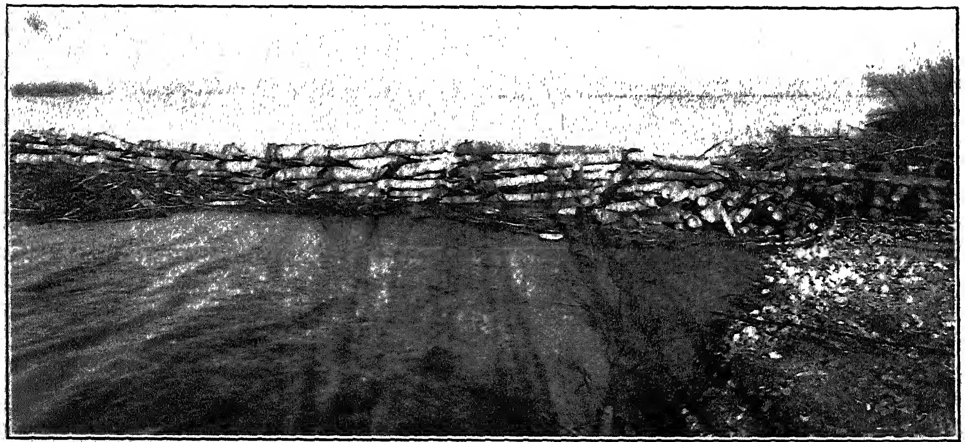
USED BY THE BURLINGTON RAILROAD IN CONSTRUCTING A BRIDGE OVER THE PLATTE RIVER AT ASHLAND, NEBRASKA. THIS FURNISHED THE INSPIRATION TO TRY THIS PILE AS AN ANCHOR FOR PERMANENT RETARDS TO PREVENT RIVER BANK EROSION, AN EXPERIMENT THAT PROVED TO BE SUCCESSFUL.

[1] Occasional publications of the American Association for the Advancement of Science, No. 3, October, 1936. Supplement to *Science*, Vol. 84. Price, 50 cents.



PUTTING IN A SECTION OF RETARDS
WHICH ARE ANCHORED UP STREAM WITH THE BIGNALL PILE SUNK BELOW THE DIGGING LEVEL OF THE RIVER.

with eroding soil and can therefore carry their load of water with less danger from flood. Lakes and reservoirs are being constructed to store excessive water and feed it gradually into the subterranean supplies and into the streams. Water for irrigation and for power development becomes more uniformly available. Fish, waterfowl and other forms of wild life breed more freely and become again a source of profit and pleasure. In the larger streams, like the Missouri, Missis-



COMPLETED RETARDS,
ONE IN THE FOREGROUND AND ONE IN THE DISTANCE. IN 90 DAYS THE RIVER BETWEEN THESE RETARDS WAS ALL FILLED IN AND IS TO-DAY GOOD FARM LAND.

sippi and Ohio, transportation takes on new life not only by water but by rail. This has been amply demonstrated by the projects on these rivers.

The records show that from 1900 to 1925 the waterway traffic in the Pittsburgh district increased 32,000,000 tons, and the railroad traffic in that district increased 116,000,000 tons. It is evident that the lower transportation rates brought about by water competition have stimulated industry as a whole. Of the total tonnage handled by the barge lines, 85 per cent. is also handled for part of the haul by the railroads.

On the Missouri River, bank protection, channel dredging, where the river does not do the work, have been largely completed as far north as Kansas City. The construction of the project to Sioux City is now well under way.

The great Fort Peck reservoir now well along towards completion is an important factor in this general conservation and development project in the Missouri River Valley. According to former Governor Arthur J. Weaver, of Nebraska, the Fort Peck project was authorized to equalize the river flow in dry years and periods of normally low water, to protect navigation and insure water for the six million acres now under irrigation and at least 4,000,000 acres that must eventually be irrigated. Besides taking care of irrigation this reservoir, by storing flood waters, will guarantee a dependable and regulated nine-foot channel at low water from Yankton and Sioux City to the Mississippi River. Transportation cost on a nine-foot channel is but half the cost on a six-foot channel. This is the standard depth maintained in the controlled areas of the Ohio, Illinois and other rivers of the Mississippi system. The Fort Peck project will cost about $80,000,000. It is said to be the largest earth fill with concrete face in the world. The maximum height is 240 feet above stream bed. The storage capacity at normal pool level is twenty million acre feet or about six times that of the Norris dam in Tennessee. The pool will be 182 miles long with 2,000 miles of shore-line and will present a water surface of 242,000 acres.

This should change the whole aspect of life in one of the great dry-land areas. It is only a sample of what may be done in many other places and in fact of what is under way in many areas.

When these great programs are completed, Old Man River will no longer be feared. Transportation, water power, fish and wild life will thrive again, and the soil, the basis of our food supply, will be conserved for all time to come.

The river will be what it used to be—a source of wealth, power and inspiration.

EXPLORATION IN THE CHOCÓ INTENDANCY OF COLOMBIA

By W. ANDREW ARCHER
SENIOR HORTICULTURIST, U. S. DEPARTMENT OF AGRICULTURE

THE Chocó Intendancy, an area of some 18,600 square miles, populated mostly by Negroes and Indians, lies in the northwestern part of the Republic of Colombia, hemmed in on all sides by mountain ranges, with the low central portion of the Atrato basin drained by a network of rivers and tributaries. Quibdó, the capital, is most accessible by river boat up the Atrato River from Cartagena, although a few travelers make the journey from Buenaventura by river boat and dugout. More recently it has been possible to enter in a much shorter time by way of airplane. From the neighboring department of Antioquia there is a six-day trail made by pack train, and it was by the latter mode that the author entered.

This trail, leaving El Carmen, follows along the mountain ridges (Fig. 1), thus escaping all the larger rivers and the impassable swamps and jungle, but at best the route is precarious and tedious, oftentimes leading through stretches of boulders or scampering up rocky inclines at the mountain streams. Once within the domain all travel is by necessity in small dugouts (Fig. 4), by which one can reach slowly and perilously nearly any point.

Historically Cordoba[1] and Alvarez[2] indicate that Balboa discovered and ascended the Atrato in 1511 and that the early Spaniards were attracted to the Chocó in search of gold and later established small settlements in order to work the mines by aid of Negro slaves. Pirates, too, were drawn to prey on the rich cargoes and deposits of the Spaniards; in fact, the filibusters, Cook and Coxon, are said to have navigated the Atrato as far as Quibdó in search of plunder.

At the height of the Spanish exploitation the annual yield of gold was nearly a million dollars, but the liberation of the slaves terminated all organization and the country straightway declined, but nevertheless great quantities of gold and platinum still exist, although in a condition requiring modern methods of extraction. The latter metal occurs in greater abundance and brought unwonted prosperity to the descendants of former slaves during the boom prices of the world war.

The climate is no inconsiderable barrier to extensive exploration; the few outsiders who have heard of the Chocó will relate tales of heat and fevers, and although the reputation thus held is fanciful to a degree, at the same time justification is not lacking. For instance, the country lies near the equator and a major portion has only a slight elevation above sea level; but even so the traveler probably suffers no more from heat than he would during an average summer in an eastern city of the United States. True enough, under the tropical sun perspiration flows at the slightest exertion, but the vast regions of green jungle, the numerous streams and the copious and frequent rains afford considerable relief. Around Quibdó the mean temperature is about 84° F., this figure being remark-

1 Francisco Cordoba M., "Nociones de geografía e historia del Chocó," pp. 25–32. 2d ed. Quibdó, 1929.

2 Jorge Alvarez Lleras, "El Chocó," pp. 16–18, 23. Bogotá, 1923.

ably constant for all the months of the year.

Admittedly our temperature and rainfall data are quite fragmentary, but since no other observations are available they would seem worthy of inclusion here. They were made by Señor Rudolfo Castro, in connection with the construction of the Quibdó-Bolívar highway, which eventually may connect the Chocó with the neighboring Department of Antioquia.

From these data it would appear that the area about Quibdó receives an annual rainfall of over 450 inches, higher by some 127 inches than Buena Vista and by 178 inches than Andogoya; areas now holding the highest records for North or South America.[3] Treadwell[4] states that the rainfall is "180 inches distributed through the year," while Miller[5] says that the annual precipitation is 400 inches, but no authority is cited for the data in either case.

Quibdó, at 175 feet above sea level, is 80 feet lower than Andagoya, while both lie about 40 miles from the Pacific Coast, although the former is about 40 miles further north than the latter and is separated by an extension of the Andes which divides the sources of the San Juan and Atrato Rivers. Quibdó is separated from the coast on the west by the Baudó River, while on the east a high range of the Andes is but a few miles distant. Altogether there is probably some special topographical relation of the Quibdó region conducive to the enormous and constant rainfall, but definite records and observations must await some future geographer.[6]

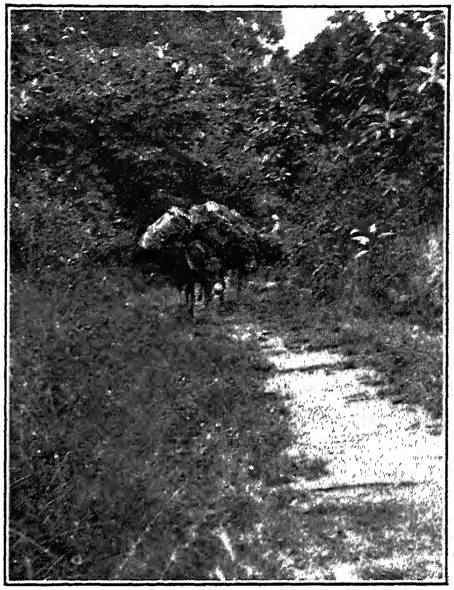


FIG. 1. CORDUROY TRAIL ALONG A MOUNTAIN RIDGE TO THE CHOCÓ.

Under such humid conditions it might be expected that the natives would suffer the consequences of violating the more fundamental laws of sanitation, but such remarked paradoxically that the Chocó was the healthiest place in the world, although all the accepted rules of sanitation were ignored, yet with none of the usual ill results attendant upon such flaunting of cleanliness.

While the diseases of the country are numerous,[7] it seems that most, *i.e.*, aside from the great scourges, malaria, tuberculosis and rheumatism, are due indirectly to malnutrition. Typhoid or dysentery are scarcely known; but this may be due to the use of rain-water for beverage purposes. To attacks of ma-

[3] W. W. Reed, *U. S. D. A. Monthly Weather Review,* Suppl. 31, pp. 1–21, 1928; P. C. Day, *U. S. D. A. Monthly Weather Review,* 54: 378, 1926.

[4] John C. Treadwell, C. R. Hill and H. H. Bennett, U. S. Dept. Commerce, Trade Prom. Ser. 40, 1926.

[5] Leo E. Miller, "In the Wilds of South America," p. 64. New York, 1918.

[6] Jorge Alvarez Lleras, *op. cit.,* pp. 7–12, 76–79.

[7] Frederick Collins, 45th Cong., 3rd Sess., Sen. Exec. Doc. No. 75, pp. 115–118. Washington, 1879.

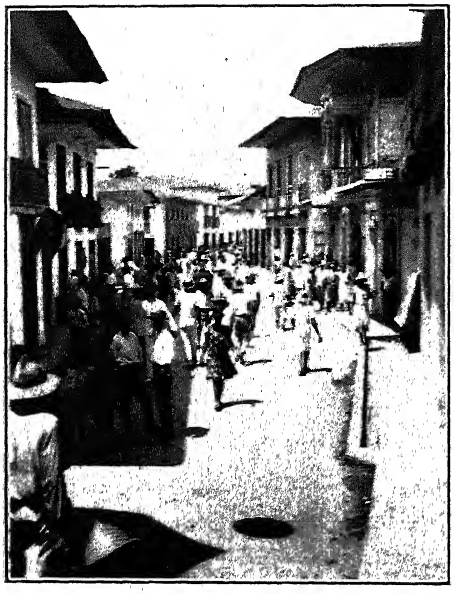


FIG. 2. MAIN STREET
AT QUIBDÓ, SHOWING MARKET DAY CROWD.

laria the natives apply loosely the terms "*la gripa*" or merely "*la fiebre*" (fever). My periodical prostrations were diagnosed by the local doctors as due to a usual acclimating fever, but nevertheless the cure was effected always by intravenous injections of plasmoquina.

Considering the universal prevalence of malaria, it was curious to note the relative scarcity of mosquitoes.[8] One would expect great hordes of them at night, yet actually they were scanty in number. Señor Castro had puzzled over the matter and finally concluded that the constant rains washed away all the larvae, and such a deduction must have a semblance of fact, because immediately after a period of several comparatively dry days it has been noted that the mosquitoes are noticeably more numerous.

Undoubtedly there are several distinct types of diseases all classed by the populace indiscriminately as "fevers."[9] There is the distinction of one, however, the intermittent fever said to be transmitted by the bedbug.

Among the children there are numerous ailments, the more common being intestinal worms and a horrible ulcerous condition known locally by the name of "*bubo.*"

Ethnologically the Chocó Negro is interesting because of his physique; all the men being magnificent, broad-shouldered specimens. Whether this pure type results as the working of the Darwinian law of the survival of the fittest, together with the superhuman labor of propelling dugouts upstream with crude paddles, or whether it harks back merely to the possibility that the original shipment of

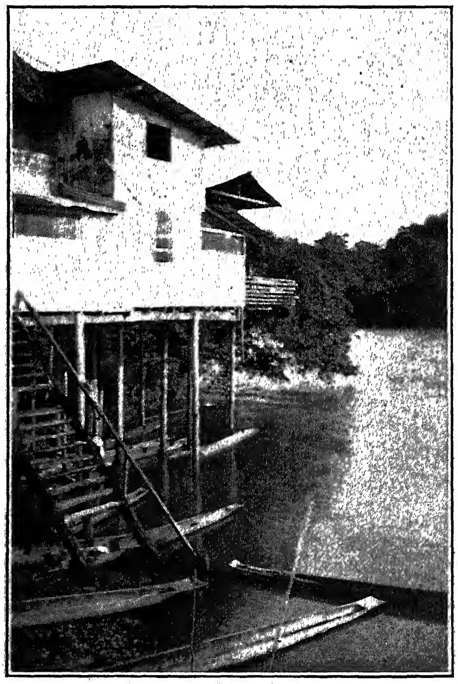


FIG. 3. VILLAGE HOUSE
IN LLORÓ, ANCIENT SPANISH SETTLEMENT.

[8] John C. Trautwine, *Jour. Franklin Inst.*, 57–58 (3rd ser., vol. 27–28), p. 42, 1854.

[9] John C. Treadwell, *op. cit.*, p. 234.

slaves to the Chocó were all captured Negroes, can be only conjectured.

The black man of Quibdó or of the other scattered villages (Fig. 5) is far from savagery, but his brother of the river bank can be designated as only semi-civilized at best. At present, true enough, it is taken for granted that a breechclout is not the proper costume for visits to Quibdó or any other of the larger settlements; the black has come to regard clothing as a desirable thing, even though his finances permit nothing more than a ragged undershirt and a tattered felt or straw hat in addition to the loincloth. The women, too, are prone to the use of a cotton dress cut according to the latest available style catalogue. All this present preoccupation with clothing has come about partly because of the influence of the Jesuit missionaries but perhaps more so from the affluence brought on some years ago when platinum fetched 18 pesos for each "*castellano*" (roughly one sixth of an ounce). During this time there was great activity in the Chocó; the Negro had much money and spent freely, although his desires were limited.

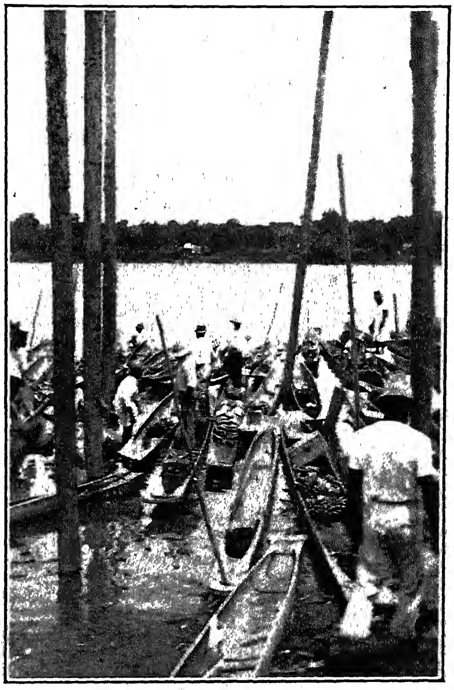


FIG. 5. RIVER MARKET AT QUIBDÓ
NOTE METHOD OF ANCHORING THE DUGOUT WITH A POLE.

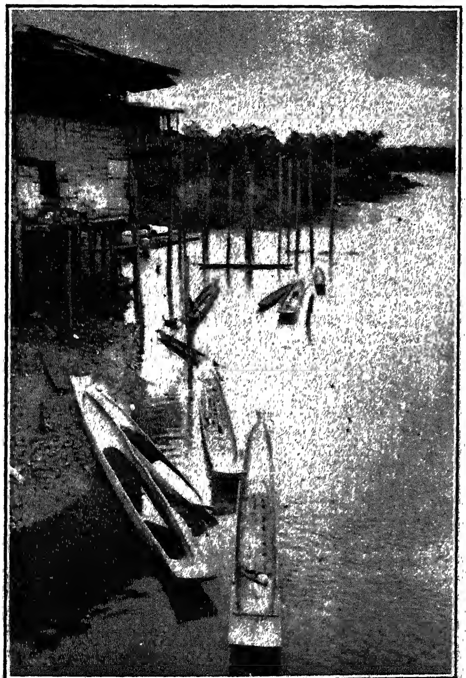


FIG. 4. PART OF RIVER FRONT AT QUIBDÓ, SHOWING CHARACTERISTIC DUGOUTS.

The chief staple of diet is the plantain, which is consumed in a variety of fashions—roasted, fried or boiled; but the banana also is eaten in large quantities. Other fruits are used; the fleshy seed of various types of the "*chontadura*" palm, *Bactris* spp., one tasting like roasted chestnuts, another like mushrooms; the avocado; pineapple; papaya; the "*sapallo*," a green-striped, short-necked squash; the squash-like "*badea*," *Passiflora quadrangularis* L.; and to a lesser extent various products of tropical trees, like the "*caimito*," *Lucuma caimito* (R. and P.) R. and S.; the "*almirajó*,"

FIG. 6. TYPICAL JUNGLE DWELLING, WITH SURROUNDING PLANTAINS

Matisia alchornaefolia Tr. and Planch.; and several edible fleshy roots of smaller plants, like the "*yuca,*" *Manihot* spp.; the "*mafafa,*" *Colocasia esculenta* (L.) Schott.; and the "*ñame,*" a cultivated yam producing enormous roots measuring sometimes 3 feet long. From a palm, *Bactris* spp., are secured terminal buds, "*cogollo,*" which are eaten raw or boiled. The lime and orange seem to thrive as scattered trees in the villages, but the people are not prone to use the fruit except as a medicinal preparation —principally to counteract fevers. My house boy, for instance, had never heard of any one drinking raw orange or lemon juice and always insisted on boiling such preparations for me.

Sugar cane thrives as an important crop, because from it is secured the crude brown sugar, "*panela,*" a much prized food of the boatmen (see Fig. 7 for mill). Corn, too, has universal use when ground to a pulp and baked in biscuit-like cakes, called "*arepas,*" but this article of food is somewhat limited because of the difficulty in the cultivation of the crop.

The constant, heavy rains contrive to keep the soil in such a soggy condition that corn plants are not highly productive. The common practice is to broadcast the seed (see Fig. 15 for broadcasting basket) during February and March or during a shorter season in September, after the trees and brush have been chopped down. These two seasons have been settled upon by the Indians as the only periods in which corn may be planted. The land can not be cleared because the felled material never dries sufficiently to be burned.[10] The corn is called locally "*maíz indio*" (Indian corn) and is said to be the same strain

[10] G. Mollien, "Travels in the Republic of Colombia in the Years 1822 and 1823," pp. 301–308. London, 1824.

used by the aborigines long before the discovery of America. The stalks attain a height of 4 to 5 feet, bearing usually two ears—although I was told that three or four ears was a common harvest. The ears measure 4 to 6 inches long, with a diameter of about $1\frac{1}{2}$ inches; the grains being predominately yellow but mixed with a few white ones.

Another food plant, though not commonly used, is the tree fern *"tasí," Alsophila rufa* Feé (Fig. 8). It is said that a person lost in the jungle can subsist for days on the pith, which is unusually free from fibers. It has a not disagreeable flavor, resembling somewhat that of Irish potato but with a degree of sliminess like okra.[11] The young leaves of *"col de monte," Phytolacca rivinoides* Kth. and Bouché are used in salads by the country folk.

[11] J. C. Piperton, Hawaiian Exp. Sta. Bul. 53, 1924.

For daily beverage the river Negro uses a black, over-parched coffee ground to a dust, or chocolate either in the bean or already extracted and prepared. But often the seed of a leguminous shrub *"potra," Cassia occidentalis* L., is employed as a substitute or as an adulterant to conserve the supply of coffee on hand.

Aside from food, there are numerous plants with reputed medicinal properties. At times, from the remarks of my guide or of a casual passerby, I was inclined to believe that nearly every plant had some medical application or other, but, of course, in many of these cases the efficacy of the remedy must be rather dubious; for example, the beautiful fern *"lorito," Trichomanes elegans* Rich., indicated by a few people as a snake-bite remedy; as was also *"chupadera," Draconteum costaricensis* Engl. (?). Nevertheless, many of the plants do possess unquestionable therapeutic value. For instance, my

FIG. 7. COMMON TYPE OF CANE MILL
EVEN THE MILLING OF THE ROLLERS IS HAND-CARVED.

friend, Dr. Cordoba, supplied me with specimens of plants which he uses constantly in his practice, *i.e.*, "*yerba dulce*," *Borreria latifolia* (Aubl.) Schum., as a diuretic; "*sombrerito del diablo*," *Cephaelis tomentosa* (Aubl.) Vahl., for relief of asthma and as an emmenagogue; "*yerba mora*," *Solanum nigrum americanum* (Mill.) Schulz., for diseases of the spleen and liver, also to wash wounds; "*Doña Juana*," *Adenostemma laveria* (L.) Kuntze, to wash wounds; and "*pacunja*," *Bidens pilosa* L., to reduce fevers; and "*mazamora*" *Brownea* sp., as an emmenagogue. Furthermore, I was told of the blistering effects of the bruised leaves of "*jasmincillo*," *Petiveria alliacea* L., much used as a counter-irritant and also to produce ulcers by malingerers to escape military service or by beggars to elicit more alms. The "*vitoria*," *Gurania wagneriana* Cogn., is said to be a counteractive for the ulcers produced by the poisonous liana, "*yateví*."[12] One Negro showed me the nearly healed scars which for four months had resisted all treatments until some one had suggested the use of powdered leaves of the "*vitoria*" applied as a dust. The "*amarga*," *Psychotria cooperi* Standl., is used as a decoction for the relief of rheumatism; "*chulco*," *Monolena cordifolia* Triana, and also *Begonia humilis* Ait. as a maceration for bilious attacks; while the cooked leaves of "*yerba de pollo*," *Vandellia diffusa* L., induce vomiting; the "*lombricera*," *Spigelia anthelmia* L., is thought to be a good cure for worms in children; "*mano de tigre*," *Neurolaena trilobata* (L.) R. Br., is considered by some natives as efficacious in the treatment of gonorrhea; and "*yerba de Adán*," *Chelonanthus acutangulus* (R. and P.) Gilg., is used to alleviate neuralgia; while "*yerba de sapo*," *Conobea scoparioides* (C. and S.) Benth., a plant with menthol-like flavor, cures toothaches. The large tree "*clavellín*" (a new species of *Brownea*) with blood-red flowers and reddish sap is widely accepted as a thoroughly good hemostatic. The cultivated shrub "*saúco amargo*" is used universally as a fever deterrent, as is the sterile, rank-growing grass "*limoncilla*," *Cymbopogon citratus* Stapf, which has a strong odor of lemon. The liana "*china*" with spiny leaves is said to be a remedy for sterility in barren women.

Aside from these medical plants sought in the wild as needed, each household has a garden of plants in pots of soil mixed with charcoal elevated in hanging gardens[13] to escape the soggy ground (Fig. 9); such plants as "*albaca*," *Ocimum basilicum* L., much used to produce sweats in the treatment of fevers; and the red-leaved "*sanguinaria*," *Oxalis hedysaroides* H. B. K., employed in the case of hemorrhage after childbirth. In these same gardens will be found onions and tomatoes, looked upon more commonly than not as medicinal rather than as food.

This undesirable wet character of the ground has brought to nil all attempts to produce pastures for cattle; because in the first place only a few grasses are suited to the peculiar climate, and secondly if a stand is secured it is soon killed out after the cows trample the grass into the ground to leave deep holes at each footprint. These holes soon fill with water and the hot sun raises the temperature to a point that the grass is killed. Thus the Chocó is a cowless land, and milk is to be obtained only in tins or from the few goats.

The few plants mentioned by no means

[12] Mentioned by Robert Blake White, "Economic and Medicinal Plants of Colombia, South America," p. 30. (Unpublished Ms. Photostat copy in Div. Plant Exploration and Introduction, U. S. D. A.)

[13] G. Mollien, *op. cit.*, pp. 301–303.

include all those of economic importance to the Negro, but merely the comparatively few which the author fortunately found in flower or fruit.

Others of interest are the "*canutillo,*" *Pariana lunata* Nees., the broad, stout leaves of which are utilized by the primitive miners to wrap gold or platinum dust;[14] the "*mora,*" *Leandra subseriata* (Triana) Cogn., which furnishes stems for the universal "*churembelas*" or home-made pipes of tin or clay, in which are smoked sections of crude cigars; the tall shrub "*jaboncillo,*" *Isertia pittieri* Standl., the leaves of which are used as a soap substitute and the waxen perfumed flowers as funeral wreaths; the "*heliotropo,*" *Hedychium coronarium* König., with sweet-scented flowers and cultivated in the public park at Quibdó; the "*cañagria,*" *Costus* sp., a cane-like plant used by the primitive goldsmiths for furbishing gold ornaments in the last stages of the crucible; "*milpesos,*" a palm which yields a splendid cooking oil from the seed; and most interesting of all the "*aceite*" tree,[15] which is tapped for an oil that is used in place of kerosene for illumination in the crude, tin wick-lamps.

For meat the Chocó people depend almost entirely upon the abundant fish which are caught in a variety of manners; by seine perhaps most commonly, by use of plant poisons and by traps, of which every family tends a few. These traps, fashioned from split bamboo or palm stems, seen scattered all along the river banks, are of two types. One, called "*corral,*" a box-like affair about two feet square, has a sliding door at the front, which is left open for the fish to enter. The owner visits the traps by dugout, closes the door and extracts the catch by means of a small dip net. The other type, called "*trinchera,*" is fence-like in that it fits across the mouth of any small stream or depression that may fill from the river. This also has a door which is closed and the imprisoned fish then dipped out with hand nets.

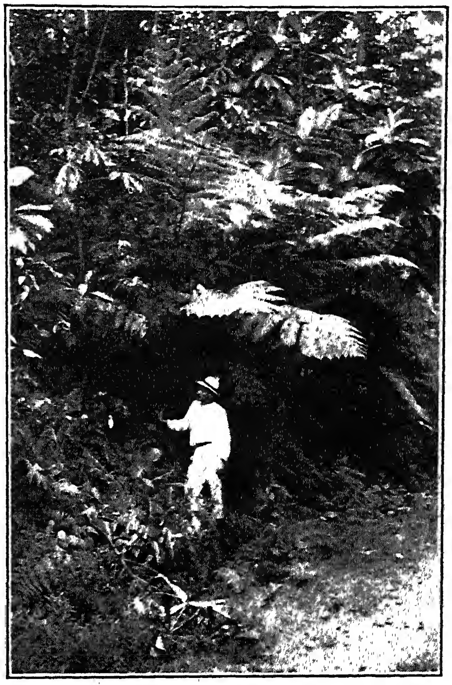


FIG. 8. THE TREE FERN "*TASI*" WHICH FURNISHES AN EDIBLE PITH.

During the early months of the year, seining in the Atrato River is the most favored because at this time the two species of fish, "*boca chica*" and "*dentón,*" migrate upstream. The seines used are handmade, even to the nets which are knotted from a heavy twine. The handles measure about 6 feet long, the hoop about 6 feet in diameter and the net as long as 10 feet. This equipment is used in midstream from a dugout, one man holding the seine while another guides the craft. During the migration period great quantities of the fish are netted and dried to be eaten or sold during the scant season.

During migration the two kinds of fish,

[14] John C. Trautwine, *op. cit.*, p. 38.

[15] Called "incive" by Cordoba, *op. cit.*, p. 21.

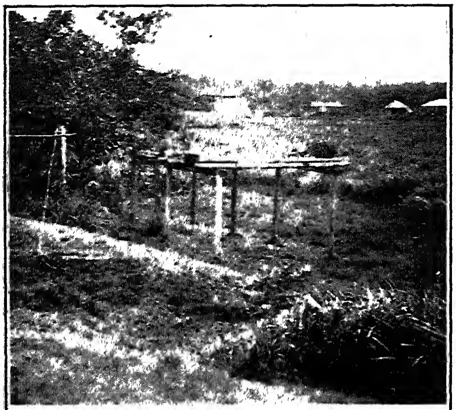


FIG. 9. HANGING GARDENS
a. TYPE COMMON TO ALL NEGRO HOMES.
b. INDIAN, UTILIZING AN OLD DUGOUT.

especially the "*dentón,*" make a roaring noise so loud that two people in opposite ends of a dugout can not converse together; although there are some days when the noise subsides considerably. Nevertheless, it is the roaring that gives a clue to the fishermen to rush out with their nets because then they are certain to make a big haul. The local Negroes designate the weird sound of the fish by the Spanish word "*roncar*" (to snore), and I once heard a woman inquire of two fishermen returning empty-handed, "What's the matter, weren't they snoring?"

Unfortunately no proper preservative was at hand to bring back specimens for the identification of these unusual fish. A fish, the "*armado,*" mentioned by Darwin[16] in the Uruguay River of Argentina, which emits a harsh grating sound heard distinctly even from beneath the water, is probably not the "*dentón*" species. Likewise the "*boom boom*" catfish of Beebe[17] is probably different. Quibdó people insist that the phenomenon is not encountered outside of the Atrato River.

Other interesting examples of the fauna are the large "*verrugosa*" snakes which coil up in the crotches of trees and which make a loud barking noise in the evening; the large ant "*conga,*" *Paraponera clavata* Fabr., which produces a barely audible, shrill squeak when annoyed or disturbed; the "*brea*" bees, *Trigona suffragata* Ckll., which inhabit hollow trees and store immense quantities of honey and resin. The natives rob the hives and utilize the resin to waterproof their dugouts and in the manufacture of primitive torches, called "*ambil.*"

INDIANS OF THE CHOCÓ

The scant information relating to the indigenous people of the Chocó region exists in the scarcely available publications of Gutiérrez,[18] Cordoba[19] and Alvarez.[20]

[16] Charles Robert Darwin, "Journal of Researches into Natural History and Geology during the Voyage of H. M. S. *Beagle* round the World," p. 98. (5th ed.) London, 1889.

[17] Charles William Beebe, "Edge of the Jungle," pp. 252–255. New York, 1921.

[18] Francisco Gutiérrez, "Informe de la prefectura apostólica del Chocó durante la administratión de los misioneros hijos del innaculado corazón de María," p. 24. Quibdó, 1929.

[19] *Op. cit.*, pp. 13–18.

[20] *Op. cit.*, pp. 16, 20, 127–130.

The four distinct groups derivative from the Carib race are distributed as follows: The Cuna along the Gulf of Darien; the Noanamá in the valley of San Juan; the Citará in the upper regions of the Atrato area (Fig. 12); the Chocó (or Baudó) in the valley of the Baudó and along the Pacific coast.

Of prehistoric days there is still less known, although Gutiérrez[21] lists a number of articles found in graves in the region of Tadó. The present author saw a pair of beautiful gold filigree ear rings which had been discovered near Quibdó in an old grave by an itinerant miner. The same man told of other articles, including gold breast plates, which he had found in excavations. The local Negroes and other inhabitants know the location of various graves, but there is a decided repugnance against opening them and tales are told of the reputed dangers of violating such places. Supposedly the ancient Indians contrived many deadly traps of weighted stones to crash down upon the grave robber, or even they arranged bowls of deadly gases or poisons.

Among the Indians themselves there are, of course, legends of various sorts handed down verbally from generation to generation, but so far as known there are no published records existing.

When Cordoba[22] published his booklet for school use, the authorities would not permit the inclusion of a legend of the genesis of the Cuna Indians. Most graciously he has given permission to translate and to publish here the account secured first hand from one of the chiefs. The story follows.

Origin of the Cunas

Since we have not been able to secure a direct translation we will give a brief sketch of the origin of the tribes of the Darien according to the "*catío*" legend.

In the theogony of the "*catíos*" there appears first a single god, eternal and uncreated, who is called Tatzitzetze, which means creator or father of all that exists. From the saliva of this god was formed Caragabí, overseer of the world who became learned in a short time.

Tatzitzetze was generous to a fault, which character profoundly displeased his son; so much so that he rose up against his father and defeating him was left as the universal arbiter.

Coming to the moment of creation, Caragabí produced from nothing a drop of water, which thrown to the earth and covered with a calabash, gave life to a male "*catío*." Not content with this work, the god threw down another drop of water from which issued a woman. To her, Caragabí gave the faculty to create drops of water, but she abused the privilege and produced drops in such profusion that it rained, thus giving origin to an infinity of Cuna Indians.

These people turned out to be intelligent and active, because they learned perfectly the use of the bow and arrow and the construction of large splendid houses. But eight days after having appeared on the earth they disavowed the authority of their god, Caragabí, and wished to kill him with arrows, but were frustrated in their intent thanks to the immortality of this sovereign. Caragabí in punishment for so great an ingratitude banished the Cunas to the river banks of the Atrato.

This conduct of the Cunas, aside from their

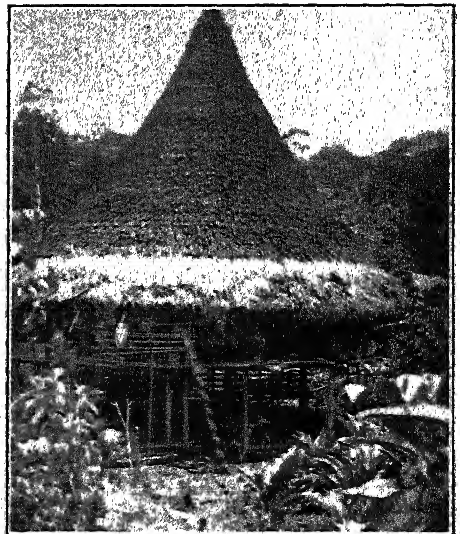


FIG. 10. CIRCULAR "TAMBU" PECULIAR TO THE INDIANS NEAR QUIBDÓ.

[21] *Op. cit.*, pp. 124–126.
[22] *Op. cit.*

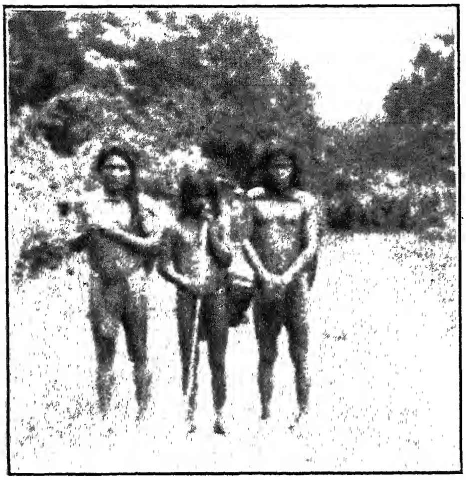


FIG. 12. TWO INDIAN MEN AND A BOY IN USUAL COSTUME, NEAR QUIBDÓ.

expulsion, gave rise, according to the legend, to continuous wars carried on between all the tribes of the Chocó.

Caragabí created for the third time a drop of water from which sprang forth Séver, and to him he taught in all perfection the use of arrows, also to rub his body with pulverized eyes of the tiger to give agility to his limbs, and to dust himself with pulverized eyes of the cavy "*guagua*" of the deer, and of the lion to increase the potency of his vision not only by day but also by night.

Séver wanted to spy on the Cunas a certain night and so he made his way toward their town, first having made a good supply of arrows which he left hidden in the sacred tree. The Cunas, upon noticing his presence, gave vigorous attack obliging him to retreat. He was followed by twenty men who expected to overtake him by following the course of the river, but Séver arriving at Genené (the sacred tree), took his arrows and with these made good account cowardly murder of their father, made vows to his dwelling in the headwaters of the Atrato.

This event awoke in Séver a mortal hate toward the Cunas, and for the space of a month he dedicated himself to the manufacture of bows and arrows. When he considered himself sufficiently armed for a new adventure against his opponents, he fell unexpectedly upon one of their dwellings and exterminated the inhabitants; without waiting for a counter attack he retired to his domain.

He then constructed a canoe according to the rules given him by Caragabí. Embarking in this with his five sons he followed the waters down the course of the Atrato, and attacked for the third time the Cunas, obtaining without great effort a victory. A month later Séver returned again, but on this occasion the Cunas resolved to make a sally. The fight took place in mid-river, and in spite of the superior number of the enemy, who maneuvered twenty canoes crowded with combatants, Séver and his five sons drove them back. In the following trip, Séver appointed his third son, Chiamo, as spy but he was surprised in a cane patch and killed by the Cunas. The father in reprisal set fire to the cane patch, thus driving from their hiding place the Cunas, and gave battle to them on a beach. There after having subdued them, he tore out the teeth of the dead and of the prisoners. These trophies he made into a string which he hung in his habitation. They became objects of superstition to the extent that they rang like bells to announce any new triumph of Séver over his enemies.

The Cunas in their turn sought revenge but with such ill luck that in a new encounter no one was left to relate the adventure. In return, those who had escaped the battle made prisoner the youngest son of Séver and carried him away as hostage. The father attacked them, setting fire to fifteen dwelling places. In the retreat of the Cunas, Emágai, son of Séver, challenged the enemy chief to single combat and emerging victor gave occasion for the chief to flee.

Since the courageous ones were not subdued by this incident, Séver returned anew against his opponents and conquering them retired afterward to his possessions satisfied with the triumph. But a few days later, while bathing in the river, he was surprised by an advance guard of the Cunas and killed. From one of the bones of the hero, the Cunas fashioned a flute but it always came apart in the middle at any attempt to play it. The sons of the leader, aware of the cowardly murder of their father, made vows to avenge it. They fell unexpectedly upon the tribe, wrought terrible punishment and then took possession of their lands.

According to Cordoba[23] the Indians are suffering gradual extinction and of the former flourishing tribes there remain but a few scattered settlements and of these only two have a semblance of organization with a "*cacique*" or chief, but there still exist a number of "*jais*" or medicine men. The "*jai*" practices a

[23] *Op. cit.*, p. 13.

sort of witchcraft and preserves secret preparations of herbs.

For many years the missionary priests have worked to convert the Indians to the Catholic religion, and in the main their success has been good, although the "*jai*" still retains considerable influence, especially in cases of illness when there must be conferences with the evil spirit or devil, who if properly approached will tell the "*jai*" which herbs must be used for remedies, or he may pronounce the case incurable.

The "*jai*" lives in a hut indistinguishable from the others in the community and his official equipment is simple, consisting usually of a carved staff and a stool, both sacred. On occasion he comes to the afflicted household, and sitting on his stool, thumps the staff in time with his chanting which may last all night if necessary to attract the devil into conversation. If the patient is important many devils of various localities may be called in, but ordinarily only the local spirit is needed.

In preparation for the incantation three young girls are chosen to prepare the special "*chicha*" or fermented drink. They are shut up in a reserved place with a quantity of the ground corn, and if any one should unwittingly spy upon them the "chicha" is thereby profaned and would need to be prepared anew. When all is ready the special beverage is placed about on the floor near the "*jai,*" in order that the devil may partake; the family of the patient become drunken from their own supply of the liquid, and the "*jai*" starts his weird chant.

If by chance the Indians should lose confidence in their "*jai*" they send word to the police of Quibdó to take action. This results usually in the departure of a deputy to visit the settlement, and if necessary to deprive the erring one of all his religious accoutrements. Thus disgraced he can no longer practice his magic and is forced to resign in favor of a son or near relative.

Sr. Cordoba once acted as such a deputy and at that time deprived the "*jai*" of a staff; a stool; various calabash shells and large wooden "chicha" bowls; wall ornaments of crossed pieces of wood cov-

FIG. 11. ALONG THE TUTUNENDO RIVER

A virgin area, where many of the botanical collections were made. Note the extreme clarity of the water.

FIG. 13. MODE OF TRAVEL IN THE CHOCÓ

ered with engraved designs; many sorts of green branches and fresh flowers used in the preparation of decoctions; and a miniature witchcraft boat of balsa wood (Fig. 14), patterned after the shape of the river steamer that visits Quibdó. This last article, now badly dismantled, had originally a wooden roof, a steering wheel and some twenty warriors variously painted, the chief armed with a saber, the rest with rifles. The *"jai"* said that he had purchased the boat from one of his brethren practitioners at a price of about twenty pesos.

Among the *"jais"* there exist great rivalry and constant witchcraft warfare. The miniature boat just described was used in such assaults; but more often one contestant may take the form of an animal, usually that of a pig, to do battle with another.

Each Citará family is a complete, self-sustaining unit, manufacturing its own utensils and implements, although in one place I learned that a neighboring artisan produced all the blowguns for the community and that another specialized in the preparation of the poisons for the blowgun darts.

The women weave many types of baskets (Fig. 15), attend to all the household duties and care for the cultivated crops; while the men build the houses, clear the land and hunt.

The men usually speak Spanish, but the women as a rule will not or can not converse in any but their native idiom. The numerical system of the Citará Indian does not extend beyond ten, and the head of one household remarked that for this reason the women could not be entrusted with commercial transactions. When asked how a woman could know when she had more than ten children, he merely shrugged his shoulders and replied that regardless she was unable to count over ten.

Phonetically, and according to the Spanish sound values, the numerical system might be represented as follows: one, *abá;* two, *umé;* three, *umpea;* four, *quimáre;* five, *uesomá;* six, *uaquirar-ambá;* seven, *uaquirara-umé;* eight, *uaquirara-umpéa;* nine, *uaquirara-quimáre;* ten, *jiquaiguará.*[24]

[24] A. L. Pinart, "Vocabulario Castellano-Chocoe (Baudo-Citarae)," Paris, 1897; Frederick Collins, *op. cit.*, pp. 118–119.

The Indian is becoming more and more dependent upon cultivated crops and domesticated animals for his food, where formerly he lived by the hunt and chase alone. Many days the family has no meat because the hunter has returned empty-handed after a long hunt, and at times like this they simply eat more rice or boiled plantains. The parrots are now wary and fly too high to be shot; the monkeys no longer frequent the haunts of man. It is a hard struggle indeed to wrest a living in competition with the increasing Negro population.

About one Indian house I noted in cultivation bananas; plantains; a species of short palm, bearing basal bunches of red fruits; corn; and *"cañabrava," Gynerium* sp. In a hanging garden (Fig. 9, *b*) made of an old canoe there were several of the medicinal *"albaca," Ocinum basilicum* L. Oftentimes are cultivated other plants, such as those for perfume, *i.e.*, *"bejucillo," Vanilla fragrans* (Salisb.) Ames and the thick-leaved *"manduro"* (not identified); the fish poisons *"chirrinchao," Phyllanthus acuminatus* Vahl., *"catalina," Clibadium polygynum* Blake, and *"varbasco de castilla," Tephrosia toxicaria* (Sw.) Pers.; and the basket dyes *"umbisca roja"* (perhaps *Arrabidea* sp.) and *"umbisca negra"* (not identified).

Commonly though the Indian depends upon chance finding of a desired plant in the surrounding forest and during the time of the expedition under discussion it was possible to note but a very few of such plants, *i.e.*, the dwarf *"nolí"* palm, *Tessmanniophoenix dianeura* Burret, which produces a kind of cotton from the leaf bases; the *"pita," Ananas magdalenae* (André) Standl., which furnishes a long stout fiber; and the *"fruto de pavo"* (not identified) with edible yellow fruits. The large fruits of the *"jagua," Genipa americana* L., are ground to a pulp and the juice anointed on the body to produce the deep blue-black, indelible stain which the Indians believe to prevent sunburn; fiber cloth of large dimensions, employed as sleeping pallets or blankets, is obtained from the cortex of the huge tree *"damagua," Pachira alba* L.[25] Most interesting of all is the clambering shrub variously called *"querá," "quedá," "querie,"* and derived from the native name *"quidai,"* meaning tooth.[26] This

[25] *Op. cit.*, p. 9.
[26] *Op. cit.*, p. 119.

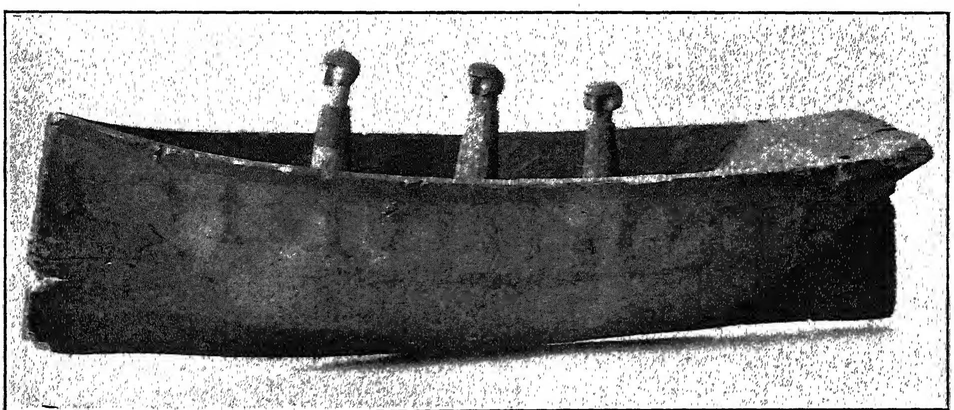


FIG. 14. WITCHCRAFT BOAT OF INDIAN *"JAI"*
(ABOUT TWO FEET LONG).

plant has been identified by Paul C. Standley, of the Field Museum, as a new species of the genus *Schradera*. The Indians of the locality all chew the plant at intervals of about six months in order to blacken and supposedly to preserve their teeth.[27] The *"tahití"* plantain is interesting in that the fruit sheaths are reputedly the source of a deadly poison for the blowgun darts.

To learn the numerous plants employed in one way or another would require much time and patience to overcome the distrust of the Indian. But probably the effort would be worthy of attempt in order to authenticate the numerous tales of secret preparations employed; for instance, there are many people who believe the Indian still knows the plant supposedly used in ancient times to produce malleable gold; secret remedies are numerous for snake bites, and some of the medicine men offer to sell such for an agreed price; there is a cure for baldness; one for toothache; and so on endlessly.

Generally speaking, the flora of the Chocó, though profuse in species, is most scanty in flowers or fruits. There seems to be no definite period of inflorescence and from my own observation and that of several local men it would appear that a large percentage of the jungle plants never produce seed but instead reproduce vegetatively, due probably to the constantly humid climate. Possibly to spend a longer time in the area might disclose more preponderance of the sexual mode or reproduction.

It was something of a disappointment to labor long hours under trying climatic conditions to be rewarded with only a comparatively few specimens. For example, in the two months spent by the author in the Chocó, only 560 specimen numbers were obtained, although observations were made and the common names secured of a considerable number of economic plants that were sterile at the time.

Future explorers in the Chocó have in store many interesting discoveries in all branches of scientific interest. The few specimens of economic plants collected by the author represent but an insignificant part of the great number that exist there. If properly approached, the Indians and Negroes would certainly reveal many of their secret remedies. A man of sufficient fortitude to resist the hardships of the climate and with a small financial outlay could within a year or two secure much valuable data and numerous specimens; material which would probably result in economic benefits to the country, to say nothing of the purely scientific results that would accrue.

The main object of the two-month expedition was the collection of plants in a country botanically unexplored. Although many of the Triana and Planchon[28] collections are cited from Chocó, yet it would appear that none was secured from within the present limits of the territory, until recently included in the Department of Cauca. Trautwine[29] was accompanied by a physician, Dr. Mina B. Halsted, who collected plants along the Atrato River, but no trace has been found of his specimens nor of a report of the data.

Aside from the botanical aspect there are scanty publications that deal with other phases of the country; Mollien[30] gives a few general observations and says that the country is scarcely known; this last statement was repeated a hun-

[27] W. Andrew Archer, *Jour. Wash. Acad. Sci.*, 24, 1934.

[28] José Triana and J. E. Planchon, "Prodomus Florae Novogranatensis," Paris, 1862.

[29] *Op. cit.*, pp. 1–2, 18.

[30] *Op. cit.*

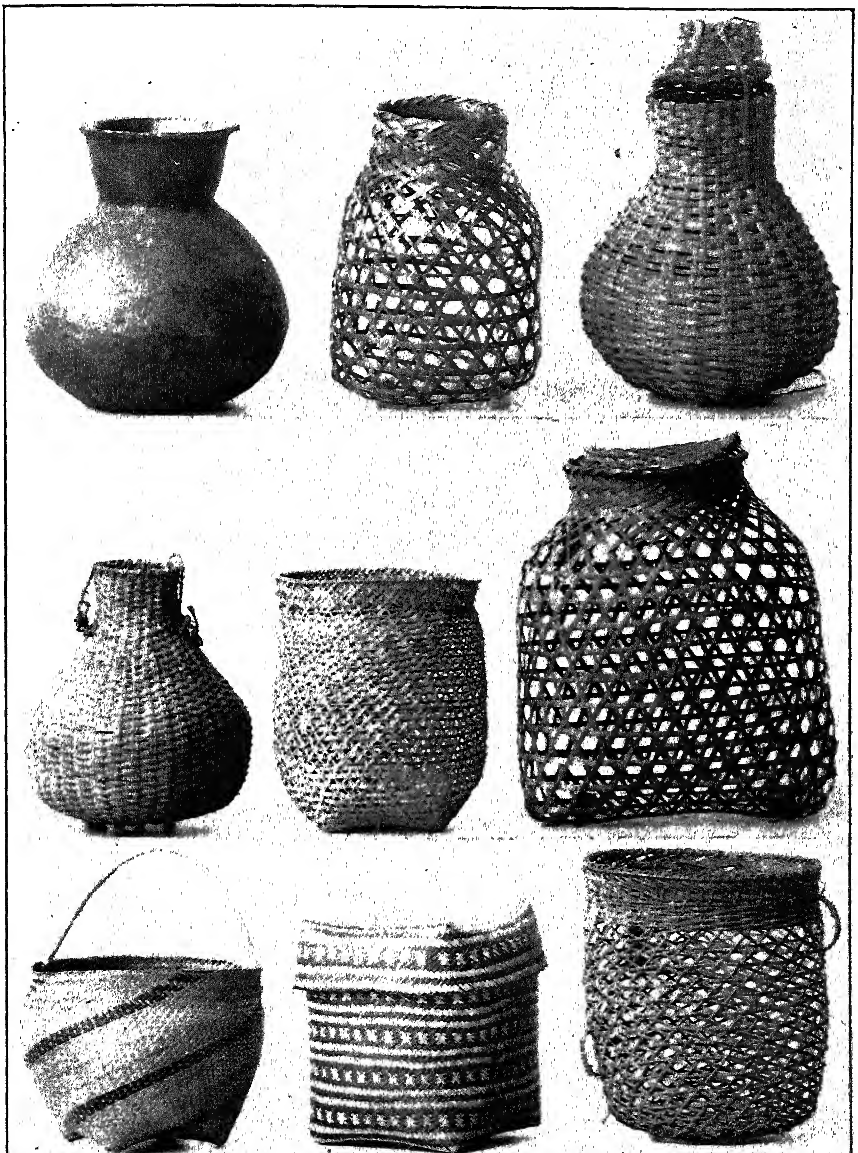


FIG. 15. INDIAN HANDICRAFT

Top Row: left, CHICHA JUG; *center,* BIRD CAGE FOR CHILDREN; *right,* BAIT BASKET FOR LIVE GRASSHOPPERS. *Middle Row: left,* CORN BROADCASTING BASKET; *center,* GENERAL UTILITY; *right,* USED TO CARRY LIVE GAME AND CHICKENS IN DUGOUTS. *Bottom Row: left and center,* NEGRO BASKETS COPIED FROM INDIAN DESIGNS; *right,* INDIAN CORN HARVEST BASKET.

dred years later by Edor,[31] Hyatt[32] and Treadwell.[33] A few other publications, Cordoba, Alvarez and Gutiérrez, though containing intimate details, are in Spanish and furthermore not available generally in libraries. In 1930, Dr. Carlos Ermisch, of Berlin, traveled rather extensively in more remote sections of the country, and undoubtedly his geological data will be published. Mrs. Elizabeth Lee Kerr, now in Cartagena, is writing her biography of long years in the Chocó jungles as a lone collector of bird skins for various museums of the United States.

Naturally the present article can not be considered as anything more than a scant statement of a few incomplete observations which the author wishes to record with the hope that later a proper expedition might be undertaken for the purpose of securing adequate records and materials from this interesting area.

For the intimate friendship bestowed by Sénor Don Rudolfo Castro B. and by Dr. Don Francisco Cordoba M. the author expresses deep appreciation. Without the cooperation of these two leading men of Quibdó it would not have been possible to have secured the more valuable data and specimens. Much credit is due to many other people of Colombia who assisted in various capacities; and to different members of the Smithsonian Institution, especially Mr. Ellsworth P. Killip and Mr. William R. Maxon for identification of plants and to Dr. Herbert W. Krieger for photographs of ethnological collections.

[31] Phanor J. Edor, ''Colombia,'' London, 1919.

[32] A. Hyatt, ''Panama, Past and Present,'' 1921.

[33] *Op. cit.*, p. 214.

HEALTH HAZARDS OF CHEMO-ENEMIES IN CONTAMINATED FOODS

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It has been aptly said that the vitamins, those invisible accessories of our diets, are the little things of nutrition. Equally so, it may be said, the heavy metals, such as mercury and arsenic, are the little things of therapeutics, the art and science of treating disease. These metals are, in many respects also, the tiniest things of toxicosis, the state of protracted ill health. Indeed, they may be the most insidious underminers—chemo-enemies—of normal cellular and tissue activity. This seems paradoxical, for apparently, on the one hand, these metals may be beneficial to health, but on the other, they may be detrimental. In other words, they can blow both hot and cold. To the uninitiated this paradox seems a surprising state of affairs. Not so to the medical scientist, who knows that the vitamins and hormones, which also exist in traces and are necessary for health, may, when abused, produce chronic illness or serious disease. Nevertheless, it is right here that much confusion exists. Laymen, and many scientists too, are apt to think only of the sudden outbursts of symptoms of poisoning as the only manifestations of dangerous effects. Dramatic, if not violent, effects do occur from the use or swallowing of large doses of the heavy metals. These, however, are not concerned in the slowly developing and continuing effects of tiny quantities to which vast populations are exposed, day in and day out, under the modern conditions of our existence.

Of particularly great concern are those heavy metals used to combat the insect pests which exist in myriads and would deprive us of the foods for our very existence. The commonest of these metals in use are lead and arsenic. We can obtain the food abundantly and economically with the aid of lead and arsenic, but these same metals may defeat the joy and the purpose of consuming that food. If we do not use the lead and arsenic, we may not have the food. If we are to have the food, we may have to take some lead and arsenic with it. It would seem a problem of relative values—some good at the expense of some harm. What we desire to know is whether our health is really in danger, if we eat such contaminated food. Many expert scientists, who have investigated the possibility, think it is. Some few people, not experts, have claimed these things to be trivial. Therefore, what experts think may prove enlightening and useful, particularly about lead, which in many respects is more important in this connection than is the arsenic.

Although lead arsenate is actually the spray residue that concerns fruit and vegetable growers and public health authorities, it is the lead which will bear emphasis, because this metal has long been recognized as an insidious menace to the health of the people. Lead has generally been regarded as a cumulative poison, a fact which has been repeatedly corroborated by the most rigid investigations. Time and again, it has been shown that lead accumulates in the viscera and bones from which it is gradually and continuously released according to conditions in the body. It is this continued streaming of lead through the body, whether the metal comes from storage-

depots within the body or from channels of absorption, that causes cumulative injuries to important bodily functions. These injuries result in manifestations of impaired health which are not generally recognized by the layman as originating with the eating of contaminated food. Growers generally do not appreciate the dangers of chronic cumulative poisoning, which is quite a different thing from acute or sudden poisoning. Chronic poisoning is really a disease and not a poisoning in the ordinary sense.

The disturbances in the beginning resemble those from some common disorders. Most practicing physicians now recognize that many people, residing in localities where insecticidal sprays are used, show symptoms which can be ascribed to lead or arsenic or both. These symptoms are characterized by loss of appetite, malaise, loss of body weight, weakness, fatigue on exertion, anemia, constipation or other gastrointestinal disturbances, and later pains in joints and nerve paralysis. Lowering of resistance to infections and predisposition to disease are also believed to occur. In the absence of other known causes, such symptoms always should arouse suspicion of injuries from lead. These symptoms are known to be more common, or are more aggravated, during spraying seasons. Conclusive evidence of toxicity can be obtained from analysis of excreta for lead and from examination of the blood, but a diagnosis of suspected poisoning can also be made without evidence of lead in the excreta. A correlation of all evidences with a history of exposure to lead generally enables a physician to arrive at a correct diagnosis.

On occasion, I have had the opportunity of making estimates of probable amounts of contaminated fruit or vegetables which might be regarded as being detrimental to health. These estimates are based on the results of experimentation with animals and on reported intoxications in man. They can only be approximate, since considerable individual variations exist, and actual conditions in the alimentary canal determine the rate and degree of absorption of the poison. Since it is believed that only one one-thousandth of a grain, or a barely visible pinch, of lead, swallowed daily for some weeks or months, may produce manifestations of illness, it was estimated in one case that from seven and one-half grains, a quantity equal to about one and a half aspirin tablets, to two teaspoonfuls, of a certain apple pomace, a dried product from apples, eaten daily by an adult for several weeks or months would be deleterious to health. For the actions of arsenic, about four teaspoonfuls of the contaminated pomace would have to be consumed, since it is believed that somewhat more arsenic than lead is required, or about five thousandths of a grain daily, for chronic intoxication. This contaminated pomace was to be used in a variety of ways; in households, for preparing jellies, vinegar and cider, and in husbandry, for feeding live stock. In another case, it was estimated that, for the effects of lead, one whole contaminated apple eaten daily for weeks or months would be hazardous to health; for effects of arsenic, three or four apples daily. In still another case, about four teaspoonsful of a contaminated cauliflower, when eaten regularly, was estimated as being capable of producing signs of ill health. Very recently I had the opportunity of considering the potential health hazards of cabbage contaminated with lead arsenate, seized in a public market in the Southwest. Analysis showed an arsenic content of 0.02 to 0.45 grain, and a lead content of 0.09 to 1.24 grain, per pound of cabbage. Since one to two grains of arsenic may be toxic or fatal to an adult, one pound of this cabbage contained one fourth to one half a toxic or fatal dose. Frequently large quantities of cabbage are used in preparations of soups, cold-

slaw, extractives and the like, which may exercise unusual solvent actions on metals due to use of heat and presence of acids, salts and proteins. Rather large portions of such culinary products may be consumed. For instance, an ordinary portion of cold-slaw eaten by an adult is said to be about four ounces, and if it were prepared from this contaminated cabbage, an adult would eat at the same time something like one sixteenth to one sixth the killing dose of arsenic, let alone a not inconsiderable amount of lead. I did not hesitate to declare this cabbage unfit for human consumption and a real menace to health, capable of producing acute poisoning. Of course, when the lead and arsenic act together, the effects are additive, and the amount of contaminated food producing illness is less than if either metal were present alone. The effects of these poisons would be even more pronounced in children than in adults, because they may consume more poison or more contaminated food in proportion to body weight.

It should be remembered that, although sprayed apples and vegetables are carefully washed by special methods, before marketing, there is a certain unremovable residue of lead arsenate which remains on the skin, around the stem and in fractures and inaccessible parts. Careless washing, or no washing at all, may leave very dangerous residues of these poisons. It is interesting to note that hydrochloric acid is used in the washing process to remove the excess of lead arsenate from apples. This same acid is a natural constituent of the digestive juice of the stomach where the unremoved lead arsenate, the so-called tolerance limit, is dissolved and made absorbable from the alimentary canal. So the water-insolubility of the lead arsenate is not a guarantee against its toxic effects in the body. It has been argued that apples are commonly wiped or peeled before eating and the stems are not consumed. However, careless wiping does not remove the poisons, and children are likely to be forgetful or inefficient. In fact, many are known to eat a whole apple, including stem and all the rest. Moreover, several such apples may be eaten daily, and result in acute poisoning. Again, the uneaten raw portions are used up in preparing vinegar, cider and the like, or are thrown to pigs, chickens or cattle. The solubility, and hence absorbability, of the poison is promoted under these conditions of fermentative acids and other products and by digestive juices in animals.

The toxic effects of lead are also manifested in domestic animals living on contaminated feeds, pastures and water supplies. This means that the sources of food supplies for people may be contaminated where spraying is done carelessly. Economic losses in live stock have been so large in sprayed regions as to cause growers to give up business. Interesting experiences are frequently related by growers which testify to the actual menace to the domestic animals in these regions. Turkeys allowed to run in sprayed apple orchards are known to have developed lead poisoning. Horses nibbling on alfalfa or other vegetation grown between the sprayed trees are reported to have died in three or four years. Drift carried to pastures during aeroplane-spraying of adjoining ranches has resulted in repeated payments of indemnities for poisoned live stock. A valley in the Pacific Northwest has received as much as 7,000,000 pounds annually of lead arsenate, and this has been going on for about twenty years. Possibly, in the neighborhood of 50,000 tons of lead arsenate have permanently contaminated the soil of this valley. But the local population assumes the poison is washed away with the rains, or blown away by the winds which generously sweep these regions. Nothing is farther from the truth. The soil retains permanently by

adsorption most of the poison strewn upon it, the poison only to be gradually released and taken up by the vegetation growing on such soil. It has been argued that rodents live contentedly in the contaminated soil, and keep on multiplying and menacing the industry even more than spray residues. Some say the bodies of these animals, and even of the people, may contain traces of lead and arsenic, and what of it, if they do.

Although lead may be found in traces in body fluids and tissues of many people, owing to the general use of sprays, ethyl gasoline and contaminated food products, this is not an argument for its harmlessness or its naturalness to the body. On the contrary, medical authorities now believe that such a general presence of lead in the population is a contributory factor to, if not a direct cause of, some common disorders whose etiology has hitherto remained obscure. Among the latter are included even such diseases as cancer, arteriosclerosis and nephritis, although there is a considerable division of opinion here. Moreover, lead never was intended by nature to be a constant or "natural" element of the body; neither arsenic, for that matter. Lead is no longer prescribed or used internally as a medicinal agent by qualified physicians; arsenic may be used, but only under supervision of a qualified physician. Colloidal lead, which has been tried in cancer, is an experimental proposition far from being generally accepted. It is misleading and improper to speak of "normal lead," as it is never present in the body in the absence of exposure, and serves no useful purpose when it is present. Certain sources of diet may not be entirely free from lead (also arsenic), but that is no justification for condoning or allowing its presence. Obviously, therefore, exposure to lead in any form or by any channel, which will cause its appearance in the body, can not be regarded other than as a hazard to health.

Investigations, which disregard established facts or fail to recognize accepted principles and procedures commonly employed in modern studies of chronic intoxications, are likely to result in premature conclusions or deceptive announcements. Just recently some commercially inspired studies, which are reported to have pooh-poohed the lead arsenate of spray residues as a health hazard, are likely to create misleading impressions and a false sense of security. Unless and until such reports are submitted to experts capable of assessing their true value, they must be regarded as being at complete variance with disinterested researches conducted by scientists the world over. The promotion of commercial enterprise with the aid of insidious poisons, such as lead, is unwarranted when done without control or discrimination and with an utter disregard of the effects of such practice on man. The burden of proof rests with those who would maintain or encourage the contrary without warning or protection of the public.

What is to be done? It would help all concerned, the growers, the enforcement authorities and the people generally, if some independent or government agency would undertake a complete "epidemiologic-toxicologic" survey of a region which has been well sprayed for years. This would get at all the facts concerning soil, animals, people, vegetation, industrial regulation, desirability of tolerance limits for the poisons and other related matters of interest. This would help the government enforcement agencies in carrying out the will of the people. The United States Department of Agriculture has already done a great deal to make the public conscious of, and protect it against, this menace, but there are apparently also limitations to its

power and influence. It is evident from the results of recent prosecutions of many violations that the public is not yet awake to the real situation. The merits of the problem are often obscured, or smoke-screened, by irrelevant matters and trivialities. Government control is interpreted as persecution of, or interference with, legitimate business. The truth is that the federal authorities are actually concerned with the economic aspects, as well as with health hazards. In fact, they are the only ones doing anything constructive about the situation. A great deal of research is being done under federal guidance to determine the best possible insecticides whose health hazard would be negligible and the costs minimal. The proper way to deal with the health hazard of heavy metals, like lead, is to eliminate their use altogether and to develop new insecticides of a totally different kind. This is actually being done experimentally, and it is not too much to hope that practical success will soon be achieved.

In the meantime, producers should avoid the use of lead arsenate or other arsenicals on vegetables like cabbage, cauliflower, Brussels sprouts, broccoli, spinach, kale, celery and snap beans, which are consumed in their entirety. They should use the most effective means possible for removing spray residue from the surface of apples and other deciduous fruits; and they should not use the skins of sprayed fruits in the production of cider, vinegar, jelly, stockfeed or other food products. Consumers should be careful to wash as thoroughly as possible all vegetables and deciduous fruits that might have been exposed to spraying. Apples that are to be eaten with the skins on should be scrubbed with a wet brush, rinsed and have the skin removed around the stem and blossom end. The parings or skins of commercially grown fruits and the pods, husks or tops of commercially grown vegetables should not be fed to poultry or live stock.

Nothing has been said here about other insecticides which have been tried, such as nicotine, selenium and fluorine. All these have proved unsatisfactory, for one reason or another. Either they are inefficient or impractical as insecticides or they are equally or more dangerous to health. The ravages of children's teeth in fluorine-infested regions of the Southwest and the monstrosities among domestic animals in the selenium-infested regions of the North should serve as sufficient warnings to the people of hitherto unsuspected or neglected hazards. These disasters should be ample reminders of the insidious menace of the metallo-poisons to people everywhere. Of immediate concern, of course, are lead and arsenic, with a greater emphasis on lead, because these are the metals which are used deliberately, though permissively within limits, in such enormous quantities. These provide a large scale exposure of thousands of people and animals and are concealed in and contaminate their articles of diet, without their knowledge or consent. Administrative regulations, which permit so-called tolerance limits of these poisons on foods, are undoubtedly applied with good intentions, and are legally essential for effective public protection under the present terms of the law. However, they are purely arbitrary and do not meet objections raised by scientists. To the latter, the health hazards of these tiny chemo-enemies are real and important. It seems clear that only those chemical substances, which are relatively non-injurious to human health and thoroughly established by scientific research on animals and men, should be used to satisfy the increasing demands for efficient insecticides.

FRANCIS AND ROGER BACON AND MODERN SCIENCE

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In my college days I became greatly impressed—as who of those days did not?—by the far-famed learning and wisdom of Francis Bacon. I read "Bacon's Essays," but none of his other works was at hand. In the "History of English Literature" which we used as a text book in my freshman year, we were told:

> Two centuries and a half of Bacon's theory in practice have revolutionized the literary, the commercial, the political, the religious, the scientific world.

We were told that Bacon's mission "was not to teach the results of investigation, but to show the method by which investigation should be made." We were told of the philosophy which Bacon undertook to supplant:

> It was a compound of the freaks of speculation. It had nothing in common with the practical science of modern times. It was the old Aristotelian philosophy robbed of its slight veneration for nature and perverted by many unwarranted interpretations. We call it scholasticism. No one of its devotees was bold enough to step from the platform of authority.

I had no means of knowing how radically false were all these statements. We were given the eulogy of Bacon by Edmund Burke:

> Who is there that upon hearing the name of Lord Bacon does not instantly recognize everything of genius the most profound, everything of literature the most extensive, everything of discovery the most penetrating, everything of observation of human life the most distinguished and refined?

Of course, we also had Pope's famous line: "The wisest, brightest, meanest of mankind."

Later, we read "Macaulay's Essays" "to improve our style," and I found that to whatever other eulogists had failed to say of Bacon's influence upon scientific thought Macaulay added. Thus he says of the "Novum Organum":

> No book ever made such a revolution in the mode of thinking, overthrew so many prejudices, introduced so many new opinions.

Again:

> the glance with which he surveyed the intellectual universe resembled that with which the archangel, from the golden threshold of heaven, darted down into the new creation.

I can not forbear giving three more sentences from Macaulay which give us a poetical picture of Bacon's outlook on the world of his day. After telling that Cowley in one of his poems compared Bacon to Moses standing on Mount Pisgah, Macaulay says:

> It is to Bacon, we think, as he appears in the first book of the Novum Organum, that the comparison applies with peculiar felicity. There we see the great Lawgiver looking round from his lonely elevation on an infinite expanse; behind him a wilderness of dreary sands and bitter waters in which successive generations have sojourned, always moving, yet never advancing, reaping no harvest and building no abiding city; before him a goodly land, a land of promise, a land flowing with milk and honey. While the multitude below saw only the flat sterile desert in which they had so long wandered, bounded on every side by a near horizon, or diversified only by some deceitful mirage, he was gazing from a far higher stand, on a far lovelier country—following with his eye the long course of fertilizing rivers, through ample pastures, and under the bridges of great capitals—measuring the distances of marts and havens, and portioning out all those wealthy regions from Dan to Beersheba.

When I first read Macaulay I had not learned from Lowell that "poetry is not

made from the understanding"; nevertheless, I was not sufficiently carried away by emotion to accept the evidences presented by Delia Bacon and her disciples that Francis Bacon had written the plays and poems of William Shakespeare.

It was after I had been teaching science for some twenty-five years that I first read Bacon's "Advancement of Learning" and "Novum Organum," and I was much disappointed in my expectation of their importance. Some ten years later I read both books again, and was more than ever puzzled at the reputation which Bacon had derived from them. Now, after twenty more years, when my time, and perhaps my judgment, have come to be considered of little value, I have undertaken to inquire into the condition of scientific knowledge and practice in Bacon's day, and to find what changes in ideas or in methods of research have occurred as a result of the "Novum Organum."

This is not easy to do. Bacon tells us ("Novum Organum," p. 332):

> The sciences which we possess have been principally derived from the Greeks, for the additions of the Roman, Arabic or more modern writers, are but few and of small importance, and such as they are, are founded on the basis of Greek inventions.

This is perhaps true regarding the Romans until their great scientific awakening one hundred years before the birth of Francis Bacon, but it is in no sense true of the Arabic scientists or of the men of Bacon's own and preceding generation.

For example, Alexander is said to have sent to Aristotle from Babylon the records of more than 1,900 years of astronomical observation. The founding of the great university of Alexandria, although it occurred after the Macedonian conquest, was due quite as much to the Jews and the Egyptians as to Greek influence. It was in this school that Euclid and Archimedes were trained, and the science of astronomy was carried forward from the earlier Babylonian beginnings. Such Greek science as had been carried over into the Roman period was virtually dead after Justinian prohibited the teaching of philosophy and closed its schools in Athens, A.D. 529. Singer, in "The Dark Ages and the Dawn," says that with the death of Theon of Alexandria, about the year 400, we part altogether with the impulse of the science of antiquity.

For several hundred years reason was abandoned for faith throughout Christian countries. These were the so-called Dark Ages. Meanwhile Arabia became the world's center of scientific research. Al Mamun, or Al Maimon, who was Caliph of Bagdad from 813 to 832, determined the sphericity of the earth and calculated its circumference from three measurements of one degree of the arc of its meridian. This was more than 650 years before Columbus.

Almaimon also collected great libraries and museums and made Bagdad the center of the world's intelligence. He also determined the obliquity of the Ecliptic. Alhazen, who died in Cairo in 1038, became the father of geometrical optics and of perspective, understood atmospheric refraction and its influence on the morning and evening twilight, explained the apparent increase in size of the sun and moon when seen near the horizon, located the conjugate foci of spherical mirrors and made many more important discoveries.

Before 1080 we have five Arabic determinations of the obliquity of the Ecliptic, all lying between 23: 34′ and 23: 35′: 52′. While the rest of Europe was hidden in the clouds of ignorance of the Dark Ages, the Saracens were covering Spain with universities, observatories and libraries. Draper, in "The Intellectual Development of Europe," says:

> When Europe was hardly more enlightened than Caffraria is now the Saracens were cultivating and even creating science. Their triumphs in philosophy, mathematics, chemistry, medicine, proved to be more glorious, and therefore more important, than their military actions had been.

All these facts seem to have been unknown to Francis Bacon, although he boasted that he had taken all knowledge for his field.

Coming down to Bacon's own country, the first great English scientist of whom we have knowledge was Roger Bacon (1214–1292), who lived 350 years before Francis Bacon. Roger Bacon was without question the most learned man of his generation in the known world. Although he was a great admirer of Aristotle, whom he calls the greatest philosopher the world has produced, he was likewise a thorough student of Arabian science, and especially of Alhazen.

Roger Bacon was a Franciscan monk. He was educated at Oxford and Paris and taught in Oxford for a number of years. He states in his "Opus Tertium" that he devoted more than twenty years to the study of languages and sciences. He writes:

> I sought the friendship of all the wise men among the Latins; and I caused young men to be trained in languages, in geometrical figures, in numbers, in the construction of tables, in the use of instruments, and in many other necessary things. . . . During this time I spent more than two thousand pounds in those things, and in the purchase of books and instruments.

His fame as a scientist became very great. His students called him Doctor Mirabilis. His teaching incurred the suspicion of his superiors in the Franciscan Order, and at the age of 43 years he was exiled to Paris and placed under restraint in the house of his order. He remained there for ten years, during which time he was forbidden to write anything for publication.

Meantime Pope Clement IV had learned of Bacon's fame and had ordered him to send for the perusal of His Holiness copies of all his writings.

Prior to this time Bacon had written but little, but in compliance with the Pope's orders he wrote in one year his "Opus Majus," "Opus Minus" and "Opus Tertium," which with his other writings he sent to the Pope. The "Opus Majus," the most recent English translation of which is a two-volume book of more than eight hundred pages, is in its essentials a defense of philosophical and scientific knowledge and explains what Bacon regarded as the true method of scientific investigation. Accordingly, it is comparable with Francis Bacon's "Advancement of Learning" and "Novum Organum," the former of which was a treatise on the importance of learning prepared for the apparent purpose of exhibiting the erudition of the author to King James, and the second for the avowed purpose of proposing a new method of acquiring a true knowledge of nature. A comparison of the "Opus Majus" and the "Novum Organum" has proved both interesting and enlightening.

It is the first book of the "Novum Organum" on which the fame of Francis Bacon as a scientific reformer largely rests. In it he undertakes to describe and classify the errors and difficulties which beset the human mind in the search for truth. The second book, which attempts to illustrate the true method of scientific investigation, has never had any standing among scientific workers. Let us, then, briefly compare his analysis in Book I with that given by Roger Bacon three and one half centuries earlier.

Francis Bacon begins by calling attention to the limitations of the human mind. He says:

Man as the minister and interpreter of nature, does and understands as much as his observations on the order of nature, either with regard to things or the mind, permit him, and neither knows nor is capable of more. . . . The subtility of nature is far beyond that of sense or of the understanding, so that the specious meditations, speculations and theories of mankind are but a kind of insanity, only there is no one to stand by and observe it.

Regarding the fallibility of human reason, Roger Bacon had said:

It is certain that never, before God is seen face to face, shall a man know anything with final certainty. It is impossible therefore for a man to attain perfect knowledge in this life, and it is exceedingly difficult for him to attain imperfect truth, and he is very prone and disposed toward whatever is false and empty; wherefore man ought not to boast of his knowledge, nor ought anyone to magnify and extol what he knows. For his knowledge is small and of little value in comparison with what he does not understand, but believes, and still smaller in comparison with that of which he is ignorant and does not know either by faith or knowledge.

And some seventeen hundred years before Roger Bacon Anaxagoras had complained as follows:

Nothing can be known; nothing can be learned; nothing can be certain; sense is limited; intellect is weak; life is short.

Francis Bacon begins the "Organum" with a series of "aphorisms," sometimes of several pages in length. These aphorisms consist of 130 numbered articles and occupy 52 pages in my copy of the "Organum." He classifies the errors and hindrances to the acquirement of knowledge under the name of "Idols." He says:

The idols and false notions which have already preoccupied the human understanding, and are deeply rooted in it, not only so beset men's minds that they become difficult of access, but even when access is obtained will again meet and trouble us in the instauration of the sciences, unless mankind when forewarned guard themselves with all possible care against them.

Aphorism 39.—Four species of idols beset the human mind, to which (for distinction's sake) we have assigned names, calling the first idols of the tribe, the second idols of the den, the third idols of the market, the fourth idols of the theater.

Aphorism 41.—The idols of the tribe are inherent in human nature and the very tribe or race of men; for men's sense is falsely asserted to be the standard of things; on the contrary, all the perceptions both of the senses and the mind bear reference to man and not to the universe, and the human mind resembles those uneven mirrors which impart their properties to different objects from which rays are emitted and distort and disfigure them.

This is a virtual repetition of his previous statement of the fallibility of human reason. Accordingly, the idols of the tribe are incapable of elimination.

Aphorism 42.—The idols of the den are those of each individual; for everybody (in addition to the errors common to the race of man) has his own individual den or cavern, which intercepts and corrupts the light of nature, either from his own peculiar and singular disposition, or from his intercourse with others, or from his reading, and the authority he acquires from those whom he reverences and admires, or from the different impressions produced on the mind, as it happens to be preoccupied and predisposed, or equable and tranquil, and the like; so that the spirit of man (according to its several dispositions) is variable, confused, and, as it were actuated by chance; and Heraclitus said well that men search for knowledge in lesser worlds, and not in the greater or common world.

Aphorism 43.—There are also idols formed by the reciprocal intercourse and society of man with men, which we call idols of the market, from the commerce and association of men with each other; for men converse by means of language, but words are formed at the will of the generality, and there arises from a bad and inept formation of words a wonderful obstruction to the mind.

Nor can the definitions and explanations with which men are wont to guard and protect themselves in some instances afford the complete remedy—words still manifestly force the understanding, throw everything into confusion and lead mankind into vain and innumerable controversies and fallacies.

Aphorism 44.—Lastly, there are idols which have crept into men's minds from the various dogmas of peculiar systems of philosophy, and also from the perverted rules of demonstration, and these we denominate idols of the theater, for

we regard all the systems of philosophy hitherto received or imagined as so many plays brought out and performed, creating fictitious and theatrical worlds. Nor do we speak only of the present system, or of the philosophy and sects of the ancients, since numerous other plays of a similar nature can still be composed and made to agree with each other, the causes of the most opposite errors being generally the same. Nor again do we allude merely to general systems, but also to many elements and axioms of sciences which have become inveterate by tradition, implicit credence and neglect.

These five aphorisms contain the gist of Francis Bacon's analysis of the errors and hindrances in human efforts to acquire a knowledge of nature. Roger Bacon had specified somewhat the same difficulties much more concisely. He says:

> Now there are four chief obstacles in grasping truth, which hinder every man, however learned, and scarcely allow any one to win a clear title to learning, namely, submission to faulty and unworthy authority, influence of custom, popular prejudice, and concealment of our own ignorance accompanied by an ostentatious display of our knowledge.

In the first-mentioned three of these hindrances Roger Bacon has stated virtually all the difficulties mentioned in Francis Bacon's essay on idols and has added a fourth hindrance which seems never to have been appreciated by the author of "Novum Organum." In regard to this fourth obstacle to the attainment of truth, Roger Bacon says:

> He especially is bereft of reason who makes a display of his knowledge and tries to publish it abroad as something marvelous.

Apart from the dissertation on idols, practically the whole of Book I of the "Organum" is taken up in criticizing the methods of scientific investigation proposed or practiced by the predecessors of Francis Bacon.

He says:

> It is vain to expect any great progression in the sciences by superinducing or engrafting new matters upon old. An instauration must be made from the very foundations, if we do not wish to revolve forever in a circle, making only some slight and contemptible progress.

On the other hand, Roger Bacon says:

> We of a later age should supply what the ancients lacked, because we have entered into their labors, by which, unless we are dolts, we can be aroused to better things, since it is most wretched to be always using old discoveries and never to be on the track of new ones.

Newton, in the generation following Francis Bacon, recognized the value of the discoveries of his predecessors when he said, "If I saw further it was because I stood on giant shoulders."

Since Francis Bacon devotes so much effort to showing that all scientific research prior to his time was worthless, it has seemed worth while to inquire into the results of some of these researches with which Bacon should have been familiar if he was to lead a scientific reformation.

One hundred and nine years before the birth of Francis Bacon one of the world's greatest geniuses was born in Florence, Italy. Leonardo da Vinci (1452–1519) became famous as a painter, sculptor, architect, engineer, anatomist, botanist and astronomer, and he was also the greatest physicist of his century. Leonardo, in telling of his methods of research, says:

> In undertaking scientific investigations I first plan a few experiments, because it is my design to base the problem on experience, and then to determine why the bodies in question are constrained to act in a given manner. This is the method that one must adopt in all researches.

Here we have a much clearer statement of the purpose of scientific induction than is given in the "Organum," but with da Vinci it was only the first step in an investigation instead of the whole process.

Da Vinci will hardly be accused of deriving his method from the writings of Greek philosophers, since he is said

to have been illiterate even in his own language, and did not acquire even an elementary knowledge of Latin till well on in life.

Francis Bacon everywhere refers to practical inventions as the highest type of scientific investigation, and Leonardo is still recognized as one of the world's greatest inventors. His death occurred only one hundred years before the writing of the "Organum."

Another forerunner of Bacon whose opinions and methods seem not to have been dependent upon the Greek philosophers was Paracelsus (1493–1540). Stillman tells us in his "Paracelsus":

> The influence of Paracelsus on Chemistry was epoch-making. By pointing out a rational and promising field for chemical activity and by his own successful application of chemically prepared remedies he inaugurated a movement which has continued without interruption and with increasing importance to the present day.

Dr. Thomas Thomson, in his "History of Chemistry" (1830), says:

> It is from the time of Paracelsus that the true commencement of chemical investigation is to be dated.

Locy, in his "Growth of Biology," calls Paracelsus the most original medical thinker of the century. Stillman tells us:

> The great popularity and consequent influence upon the time of the works of Paracelsus is evidenced by the bibliography of his printed works compiled by Sudhoff, in which no less than two hundred and fifty are recorded as appearing before 1600.

The writings of Paracelsus must be included among the "few modern attempts at scientific investigation" which Bacon rated as of small importance.

Coming nearer to Bacon's own time, we have the anatomist Vesalius (1514–1564), who died three years after Bacon was born. Singer says of Vesalius ("The Dark Ages and the Dawn," p. 157):

> Taken as a whole, his work is one of the most marvelous efforts of scientific observation that has ever been launched upon the world.

Vesalius's great work on the structure of the human body appeared in 1543, seventy-seven years before the "Organum." Locy, in "Biology and Its Makers," says:

> The book of Vesalius laid the foundation of modern biological science. It is more than a landmark in the progress of science—it created an epoch.

Another famous scientist whose work should have been known to Bacon was Johann Baptista van Helmont, a native of Brussels, who, Stillman tells us, was the most prominent chemist of the first half of the seventeenth century. Van Helmont visited London in 1604–1605 while Bacon was writing "The Advancement of Learning" and was received with honor.

Turning to another field of scientific research, in 1543, eighteen years before the birth of Bacon, Nicholaus Copernicus published his great work, "De Orbium Coelestium Revolutionibus," in which he set forth the evidence for the heliocentric theory of the solar system. This book led to one of the greatest conflicts ever waged in the warfare of science, which conflict had its climax in Bacon's lifetime. Two years before the publication of "Novum Organum" the works of Copernicus were ordered burned, and Galileo was in the midst of his second and fatal controversy with the Inquisition.

In "The Advancement of Learning" Bacon recites a number of exploded dogmas, among them "the absurdity of which have thrown men upon the extravagant idea of the diurnal motion of the earth, an opinion which we can demonstrate to be most false."

This was written five years after the burning of Giordano Bruno, who had

been in England twenty years before, had written some of his most important books while there, had held a disputation with some learned doctors at Oxford over the rival merits of the Ptolemaic and the Copernican theories of the universe and had written and published in England an exposition of the Copernican theory.

Later, Bacon seems to regard the diurnal motion of the earth as at least a debatable question. In the "Organum," which was written two years after the publication of Kepler's Laws, and after Bacon had accepted the fact of the revolution of the satellites of Jupiter, he says, speaking of the supposed revolution of the heavens about the earth:

> The motion in question is, according to common and long received opinion, considered to be that of the heavenly bodies. There exists however, with regard to this, a considerable dispute between some of the ancients as well as moderns, who have attributed a motion of revolution to the earth. A much more reasonable controversy perhaps exists (if it be not a matter beyond dispute) whether the motion in question (on the hypothesis of the earth's being fixed) is confined to the heavens, or rather descends and is communicated to the air and the water.

What this means, I do not know, unless it refers to the trade winds and some of the ocean currents which had been mentioned by the early navigators; but it certainly does not mean that Bacon was an advocate of the heliocentric theory or that he has added to the development of modern astronomy.

Although not favorably impressed by Galileo's arguments in the field of astronomy, Bacon seems to have been influenced by some of his experiments in mechanics. After Galileo's demonstration that all bodies fall with equal velocities except as they are hindered by a resisting medium, Bacon, after stating that twenty pounds of lead fall no faster than a single pound, says:

> Inquire whether the quantity of a body may be so increased as that the motion of gravity shall be entirely lost, as in the globe of the earth which hangs pendulous without falling. Quaere, therefore whether other masses may be so large as to sustain themselves? For that bodies should move to the center of the earth is a fiction; and every mass of matter has an aversion to local motion, till this be overcome by some stronger impulse.

And Macaulay tells us that Bacon had an amplitude of comprehension such as has never yet been vouchsafed to another human being. At least, there was a development of modern astronomy before Bacon wrote the "Organum." Besides the arguments of Copernicus, Tycho Brahé had carried on his famous observations at Uranienburg and elsewhere, Kepler had computed the laws of planetary motion, Galileo had shown the revolution of Jupiter's satellites and the phases of Venus.

It is not even necessary to go outside the circle of Bacon's acquaintances to show that science was not contemptible before the publication of either of his books. In 1600, William Gilbert, chief physician to Queen Elizabeth, published his "De Magnete," the first great work on physical science which was produced in England. Galileo, who is often called the originator of modern science, says of Gilbert's book that it is "great to a degree to be envied." Dr. Thomas Young, who was regarded as the greatest scholar of his day in England, the interpreter of the Egyptian inscriptions, the founder of the undulatory theory of light and the first man to measure the wave-length of light, published a course of lectures on "Natural Philosophy and the Mechanical Arts" in 1907. In these lectures he gives especial attention to the history of the development of physical science. He says of William Gilbert:

> The first of the moderns whose discoveries respecting the properties of natural bodies excite our attention by their novelty and impor-

tance is Dr. William Gilbert, of Colchester; His work on Magnetism published in 1590, contains a copious collection of valuable facts, and ingenious reasonings. He also extended his researches to other branches of science and, in particular to the subject of electricity.

Gilbert not only published the results of his investigations which established that the earth, itself, is a great magnet, and nearly all the other facts known about magnetism until the discovery of electromagnetism more than two hundred years later, but he described his method of research. In the opening paragraph of his preface he says:

Since in the discovery of secret things and in the investigation of hidden causes, stronger reasons are obtained from sure experiments and demonstrated arguments than from probable conjectures and the opinions of philosophical speculators of the common sort; therefore to the end that the noble substance of that great loadstone our common mother (the earth) still quite unknown, and also the forces extraordinary and exalted of this globe may the better be understood, we have decided first to begin with the stony and ferruginous matter, and magnetic bodies, and the parts of the earth that we may handle and perceive with the senses; then to proceed with plain magnetic experiments and to penetrate to the inner parts of the earth.

In another place he says:

This natural philosophy is almost a new thing, unheard of before; A very few writers have simply published some meager accounts of certain magnetic forces. Therefore we do not at all quote the ancients and the Greeks as our supporters, for neither can paltry Greek argumentation demonstrate the truth more subtly nor Greek terms more effectively, nor can both elucidate it better. Our doctrine of the loadstone is contradictory of most of the principles and axioms of the Greeks.

At the time of publication of "De Magnete" Galileo, who was twenty-four years younger than Gilbert, had already made his memorable experiment on falling bodies and was lecturing in Padua and laying the foundations of the science of mechanics.

Another contemporary of Bacon who ranks among the most distinguished of the world's scientific investigators was William Harvey (1578–1667). Harvey was seventeen years younger than Bacon, and began his practice of medicine in 1602, after graduating from Cambridge and spending four years at the University of Padua under the special instruction of Fabricius. Besides his medical practice he gave public lectures on anatomy while he was carrying on extensive investigations in various fields of biology. He became Bacon's personal physician, which must have given Bacon an opportunity to know something of the biological science of his day had he been so inclined. During this period Harvey demonstrated the circulation of the blood through the arteries and veins and lectured on this topic, though his great work, "De Motu Cordis et Sanguinis," was not published until 1628.

Locy ("Biology and its Makers," p. 52) says of Harvey's influence on science:

He was a comparative anatomist as well as a physiologist and embryologist; he had investigated the anatomy of about sixty animals and the embryology of insects as well as vertebrates, and his general influence in promoting biological work was extensive. His work on the movement of the blood was more than a record of careful observations; it was a landmark in progress.

While Harvey must have been well acquainted with Bacon, there is no indication that his methods of research were influenced by this acquaintance. Bacon tells us in "Advancement of Learning":

Medicine has been rather professed than labored and yet more labored than advanced, as the pains bestowed thereon were rather circular than progressive; for I find great repetition and but little new matter in the writers of physic.

Aubrey's "Biography of Harvey," quoted in Locy's "Growth of Biology," says:

He (Harvey) had been physitian to the Lord Ch. Bacon, whom he esteemed much for his wit and style, but would not allow to be a great philosopher. Said he to me, "He writes philosophy like a Lord Chancellor."

In this very inadequate review of some of the scientific work in Europe prior to the publication of the "Novum Organum" mention has been made of at least ten men who are still regarded as world leaders in their fields of investigation, while nothing has been said of their numerous contemporaries whose names appear in every history of the science of that period.

Lord Bacon gives no indication that he recognized the great scientific revival of his own generation. He seldom refers to any scientific investigator except Gilbert, and to him only contemptuously. He does recognize Galileo to the extent of wondering why he does not discover how large a body must be in order that gravitation may cease to act upon it; but he makes frequent mention in both "The Advancement of Learning" and the "Organum" of "Gilbert who has written a painful and elaborate work upon the magnet." He says: "So the alchemists have made a philosophy from a few experiments of the furnace, and Gilbert another out of the loadstone."

He refers to men who "waste all their time on probing some solitary matter, as Gilbert on the magnet and the alchemists on gold."

He tells us that "The electric energy (of which Gilbert and others after him have told so many fables) is only the energy excited by gentle friction."

Why Bacon selected Gilbert as his especial example for adverse criticism he does not tell us, and it is the purpose of this paper to let Bacon tell his own story. However, it is a fact that Gilbert had proposed a method of scientific investigation and had demonstrated its efficiency twenty years before the publication of the "Organum," and that although Gilbert had been known to be capable of self defense during his lifetime, he had died two years before the publication of "The Advancement of Learning," and eighteen years before the "Organum."

Bacon tells us in his introduction to the "Organum":

Our method, though difficult in its operation, is easily explained. It consists in determining the degree of certainty, whilst we, as it were, restore the senses to their former rank, but generally reject that operation of the mind which follows close upon the senses, and open and establish a new and certain course for the mind from the first actual perceptions of the senses themselves.

Let me quote a few excerpts from the list of aphorisms:

Aphorism 8.—Even the effects already discovered are due to chance and experiment, rather than to the sciences; for our present sciences are nothing more than peculiar arrangements of matters already discovered, and not methods for discovering or plans for new operations.

Aphorism 11.—As the present sciences are useless for the discovery of effects, so the present system of logic is useless for the discovery of the sciences.

Aphorism 19.—There are and can exist but two ways of investigating and discovering truth. The one hurries on rapidly from the senses and particulars to the more general axioms, and from them as principles and their supposed indisputable truth, derives and discovers the intermediate axioms. This is the way now in use. The other constructs its axioms from the senses and particulars, by ascending continually and gradually, till it finally arrives at the more general axioms, which is the true, but unattempted way.

In Aphorism 69 Bacon gives a sort of summary of his doctrine as follows:

In the first place, the impressions of the senses are erroneous, for they fail and deceive us. We must supply defects by substitutions, and fallacies by their correction. Secondly, notions are improperly abstracted from the senses, and intermediate and confused when they ought to be the reverse. Thirdly, the induction that is employed is improper, for it determines the principles of science by simple enumeration, without adopting exclusions and resolutions, or just separations of nature. Lastly, the usual method of discovery and proof, by first establishing the most general propositions, then ap-

plying and proving the intermediate axioms according to them, is the parent of error and the calamity of every science.

It is difficult for one so poorly equipped in philosophical methods as myself to distinguish clearly between this method which Bacon condemns and the method which he recommends in his Aphorism 117.

Our course and method, however (as we have often said and again repeat), are such as not to deduce effects from effects, nor experiments from experiments (as the empirics do), but in our capacity as legitimate interpreters of nature, to deduce causes and axioms from effects and experiments; and new effects and experiments from these causes and axioms.

And although anyone of moderate intelligence and ability will observe the indications and sketches of many noble effects in our tables and inventions (which form the fourth part of the *Instauration*) and also in the examples of particular instances cited in the second part, as well as in our observations on history (which is the subject of the third part); yet we candidly confess that our present natural history, whether compiled from books or our own inquiries, is not sufficiently copious and well ascertained to satisfy, or even assist, a proper interpretation.

Here Bacon seems to admit that not even he has yet been able to devise anything which will assist in the interpretation of nature, though in his 73d aphorism he says:

Of all signs there is none more certain or worthy than that of the fruits produced, for the fruits and effects are the sureties and vouchers, as it were, for the truth of philosophy. . . . We think some ground of hope is afforded by our own example, which is not mentioned for the sake of boasting, but as a useful remark. Let those who distrust their own powers observe myself, one who have amongst my contemporaries been the most engaged in public business, who am not very strong in health (which causes a great loss of time), and am the first explorer of this course, following the guidance of none, not even communicating my thoughts to a single individual; yet having once firmly entered the right way, and submitting the powers of my mind to things I have somewhat advanced (as I make bold to think) the matters I now treat of.

Finally, Bacon tells us near the close of Book I that what he has said so far is merely to convince his readers that no one has yet acquired the true art of interpreting nature. In "The Advancement of Learning" he had said:

Lastly, I may lament that no fit men have been engaged to forward those sciences which yet remain in an unfinished state. To supply this want it may be of service to perform, as it were, a lustrum of the sciences, and take account of what has been prosecuted and what omitted.

Yet Bacon lived during the most productive period of scientific research the world had ever known.

Since Bacon concludes that in Book I he has convinced his readers of the necessity of a new method of interpreting nature, he proceeds in Book II, which in my copy consists of 102 pages, to describe and illustrate his method by instructions for investigating the "Form of Heat." Bacon's use of the term "form" is not perfectly clear to me. I will quote his definition.

The form of any nature is such, that when it is assigned the particular nature infallibly follows. It is therefore, always present when that nature is present, and universally attests such presence, and is inherent in the whole of it. The same form is of such a character, that if it be removed the particular nature infallibly vanishes. It is therefore absent whenever that nature is absent, and perpetually testifies such absence, and exists in no other nature. Lastly, the true form is such, that it deduces the particular nature from the source of essence existing in many subjects, and more known (as they term it) to nature, than the form itself. Such then is our determination and rule with regard to a general and perfect theoretical axiom, that a nature be found convertible with a given nature, and yet such as to limit the more known nature, in the manner of a real genus.

The aim of Bacon's proposed system, as nearly as I can make it out, is the discovery of these "forms" in nature. This is as far as possible from my understanding of the nature of physical science, which is the investigation of mechanical relations between the various phenomena of the physical universe.

Bacon seems to use the term nature somewhat in the sense in which we use the term property. He speaks of a body as an aggregate of simple natures and describes the natures of gold as yellow, heavy, of a certain weight, malleable and ductile to a certain extent, and the like. Thus he means by bodies of the same natures what we would describe as bodies having the same properties. The "form" of a body or of a phenomenon seems, then, to mean something upon which all its various properties depend. It suggests the ancient idea of the spirit or essence of a body or an event.

It has seemed to me that the most nearly understandable of the various attempts at explaining Bacon's meaning which I have read is found in Adamson's article on Francis Bacon in the ninth and following editions of the "Britannica." Adamson says:

> It appears clear that in Bacon's belief the true function of Science was the search for a few fundamental physical qualities, highly abstract and general, the combination of which give rise to the simple natures and complex phenomena around us.

Looked at from this standpoint it is no wonder that Bacon saw nothing praiseworthy in the science of his day. Galileo was not looking for forms, but was trying to find out the relation between the velocity and the time of free fall of a body, or the relation between the time of vibration of a pendulum and its length, or the question of the rotation of the earth rather than the revolution of all the heavenly bodies around it. Gilbert was determining the location of the great magnet which controlled the orientation of the magnetic needle. Harvey was determining the character of the movement of the blood in the arteries and veins. None of the investigators of his day was trying to determine "the form of heat" or motion or magnetism or gravity. Even Newton, one generation later, was determining only that gravitation was the same throughout the solar system. Accordingly, when Bacon tells us, "Physics treats of the principles of things, the structure of things and the variety of things," he is not speaking of any physics which has existed in modern times. Necessarily, his influence on modern physics has been nil.

This assertion would seem still more certain were we to follow through the 95 pages of Bacon's description of the proper method for determining the "form of heat."

He first gives a table of twenty-seven "Instances Agreeing in the Form of Heat." These are of various kinds, as "The heat of the sun," "Flame of every kind," "Natural warm baths," "Strong spirits of wine when poured upon whites of eggs causing them to grow hard and white," "Strong vinegar and all acids on any part of the body not covered by epidermis," "Aromatic substances which, while not hot to the touch are found by the tongue and palate to be warm when chewed," and many others.

Later he gives us a "Table of the Degrees or Comparative Instances of Heat." In this table he gives forty-one examples. Some of these do not show the accurate observation which Macaulay attributes to Bacon. Thus he says in Example 39:

> A brick or stone or hot iron, plunged in a basin of cold water and kept there for a quarter of an hour or thereabouts, retains such a heat as not to admit of being touched.

He also tells us that water freezes more easily after having been gently warmed.

He then gives examples of the "Exclusive Table, or the Rejection of Natures from the Form of Heat." In this table he tells us what natures to reject in deciding upon the form of heat because they are not common to all bodies which partake of this form. He tells us,

> It must be observed that the form of anything is inherent (as appears clearly from our premises), in each individual instance in which

the thing itself is inherent, or it would not be a form. No contradictory instance therefore can be allowed.

As a final result of his discussion regarding the form of heat Bacon says; "From the instances taken collectively as well as singly, the nature whose limit is heat seems to be motion."

This induction Bacon terms "The First Vintage of the Form of Heat," that is, it is the primary induction which is to be used in building up other inductions. Motion is not "the form of heat," but only one of the "natures" of that form. Nevertheless, Will Durant tells us in "The Story of Philosophy," "He (Bacon) finds after long analysis an exact correlation between heat and motion; and this conclusion that heat is a form of motion constitutes one of his few specific contributions to natural science."

A relation of heat to some form of motion was suspected, not only by Bacon, but by Descartes, Amontons, Boyle, Hooke and Newton, and was finally demonstrated by Rumford and Davey nearly two hundred years later. However, it took fifty years longer to demonstrate that, to use our present terminology, heat is a form of energy, still from Bacon's definition energy is not "the form of heat."

In marked contrast to Francis Bacon's proposed system of successive inductions is Roger Bacon's statement of the proper method of scientific investigation. In the copy of "Opus Majus" which is before me he devotes fifty-one pages to a discussion of the method of experimental science. He tells us:

This science has three leading characteristics with respect to other sciences. The first is that it investigates by experiment the notable conclusions of all those sciences. For other sciences know how to discover their principles by experiments, but their conclusions are reached by reasoning drawn from the principles discovered. But if they would have a particular and complete experience of their own conclusions, they must have it with the aid of this noble science. . . . For there are two modes of acquiring knowledge, namely, by reasoning and by experience. Reasoning draws a conclusion, and makes us grant the conclusion, but does not make the conclusion certain, nor does it remove doubt so that the mind may rest on the intuition of truth, unless the mind discovers it by the path of experience. . . . Aristotle's statement, then, that proof is reasoning that causes us to know is to be understood with the proviso that the proof is accompanied by its appropriate experience, and is not to be understood as the bare proof. Reasoning does not suffice, but experience does. . . . He therefore who wishes to rejoice without doubt in regard to the truth's underlying phenomena must know how to devote himself to experiment.

As a comparison with Francis Bacon's investigation of the form of heat, we may consider Roger Bacon's explanation of the rainbow and the coronas sometimes seen around the sun and the moon.

He begins by developing the geometrical optics of the rainbow and the solar coronas as he understands them. He shows that the rainbow is due to light reflected from water drops, as may be seen in mist and sprays of water and in dew drops, while coronas and haloes are due, as he believes, to refraction. He is not clear about the nature of diffraction, as who can be without a knowledge of the undulatory theory? However, he describes the formation of diffraction fringes around a small aperture through which light is observed.

He describes the position of the rainbow with reference to the sun, and concludes that the sun, the eye of the observer and the center of the arc of the rainbow must be in the same straight line, also that the angle made by the rays from the circumference of the rainbow arc and its central axis at the eye of the observer must be 42 degrees, and hence that no rainbow can be visible to one when the sun behind him is more than 42 degrees above the horizon, and he discusses the times of year when rainbows may be seen at different latitudes on the earth.

In this calculation he does not take into consideration the double refraction and reflection of the light rays from the two surfaces of the water drops, and accordingly the different angles at which the cone of rays may reach the eye from drops of different radius.

He is not able to explain the separation of colors in the rainbow nor in the spectrum produced by a prism, as no one was until Newton showed that the various colors were properties of the sunlight. Bacon thought they were due to some property of the eye, as their recognition is now known to be.

One of the questions which interested Bacon, and which he could not answer to his own satisfaction, was the cause of the scintillation of the stars. He thought of the possibility of refraction due to some unsteady, non-homogeneous body between us and the stars, but he believed that refraction occurred only when light passed from one medium to another, and could not be due to the atmosphere after light had once entered it. He describes the effect of the difference in density of refracting media upon the direction of bending of oblique rays in passing from one to the other, but does not recognize the effect of density variation within a given medium.

Bacon taught that while the rainbow was due to reflection the coronas and haloes around the sun are due to refraction, though he could not specify the refracting surfaces as we do at the present time. So far as was possible with the knowledge of his time, his explanation of the rainbow is a masterpiece, though his geometrical optics was largely derived from the writings of Alhazen. He refrained from proposing explanations of phenomena which he could not verify, and was consistent with his theory of experimental science, namely, that his conclusions as well as the data for his inductions must be verified by experience. This is the one step in the scientific method which seems to have been first insisted upon by Roger Bacon. By its adoption the modern scientific method became complete. Nothing has since been added to it.

The thorough mastery of the subject of geometrical optics by Bacon is shown in his statements of the possibility of the construction of the telescope and microscope. At the close of his report on optical science in the "Opus Majus" he says:

> The wonders of refracted vision are still greater; for it is easily shown by the rules stated above that very large objects can be made to appear very small, and the reverse, and very distant objects will seem very close at hand, and conversely. For we can so shape transparent bodies and arrange them in such a way with respect to our sight and objects of vision, that the rays will be refracted and bent in any direction we desire, and under any angle we wish. We shall see the object near or at a distance. Thus from an incredible distance we might read the smallest letters and number grains of dust and sand owing to the magnitude of the angle under which we viewed them, and very large bodies very close to us we might scarcely see because of the smallness of the angle under which we saw them, for distance in such vision is not a factor except by accident, but the size of the angle is.

One can only conjecture what Roger Bacon might have done for the cause of science had he been allowed to follow up his proposed method, but only three years after he was freed from his confinement in Paris the daring and frankness of his teaching caused his arrest and imprisonment for fourteen more years, and he was set free only at the age of 77, and a short time before his death. As it is, he seems to have been the first man to state clearly the scientific method of thinking which has transformed a large part of the civilization of the world in the past three hundred years. In the development of this method of thinking the world has known only one Bacon, and his name was not Francis.

A PRAGMATIST EXAMINES THE DISCARD OF MECHANISTIC PSYCHOLOGY

By Dr. BENJAMIN R. SIMPSON
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College studies of to-day at their best make a vital and varied appeal to the youth of real intellectual ability. The physical sciences point the way to new achievements in radio, television, synthetic chemistry—products of the mind of man. History illumines the human drama as it has been enacted in historic times, with its interplay of motives which have turned the tide of human destiny hither and yon. Biography selects the unusually significant or picturesque human life and concentrates upon the interpretation of its struggles and achievements. The novel and the drama portray the complexities of human emotion. Shakespeare is the acknowledged master in the portrayal of human nature.

Thus the arts, humanities and sciences, which constitute so large a part of a modern college curriculum, seem to illuminate the life of man and the product of his intellectual explorations. And what of psychology? Should not psychology be counted upon to lead the eager student into the inner sanctuary, the scientific study of man himself? Presumably this should deal with what is most significant in man—his impelling drives and purposes, his satisfactions and disappointments, his learning, the attitudes which may culminate in a Napoleonic career, and how more intelligent direction of learning may be counted upon to result in greater human values for all parties concerned. One wants to know how groups, both local and national, may hope to achieve more lasting forms of satisfaction and avoid destructive conflicts. Primitive man, to be sure, had to struggle with problems of a physical sort, but now come problems of adjustment of the individual within himself and with his neighbor. What a bonanza to the youthful intellect—the science which gives the accumulated researches of the masters in this study of the life of man!

If such is the expectation, what must be the disillusionment when the eager student turns the pages written by the self-admitted leader of the only (?) scientific movement in present-day psychology and finds that there is in reality no such thing as mind or consciousness; that "Belief in the existence of consciousness goes back to the ancient days of superstition and magic," and that the scientific psychologist has "dropped from his scientific vocabulary all subjective terms such as sensation, perception, image, desire, purpose, and even thinking and emotion as they are subjectively defined." Also that other psychologists not so doing are without the pale and barren of production. Emotion, for example, becomes "an hereditary pattern reaction involving profound changes of the bodily mechanism as a whole, but particularly of the visceral and glandular systems." As one critic has expressed the situation which must face the student in his attempt to understand such a human emotion as fear: "Fear is that psycho-galvanic-blood-pressure-breathing-ratio score falling within the middle fifty per cent. of the scores made by any given group of subjects exposed to the firegong-electric punishment test, known as Shock U (copies at the bookstore, 7 cents each)." Presumably the student would be advised that he must hence-

forth be on guard against thinking that he has ever felt fear as a mental state; that such is a mere delusion, and that his emotion is in reality only a bodily reaction.

Nor is that the worst of the story, for there is no such thing as human choice or human purpose. Lincoln was a mechanical robot and, as such, could not have done other than he did, for his responses were inevitably determined by the stimuli which played upon him. What becomes of the study of Lady MacBeth or of Jean Valjean!

How is one to account for such a travesty as this? Surely science must start with what is already accepted universally or prove it false. It must start with life and apply to life in a way that works. Otherwise it fails to be a contribution and fails to meet the criterion of science. Such psychology as the above explains nothing. It demolishes everything. A scientific theory is accepted only because it works, and such theories as the above do not work. They are not acted upon by the very persons who teach them. What behaviorist tries to persuade his friend who has just broken his leg that consciousness of pain is a mere delusion, or the judge in court that the accused at the bar of justice was a helpless mechanical puppet solely at the mercy of the stimuli playing upon him! Can it be that this belief is just a new fashion and as foolish as some other fashions supposedly less intellectual have been? Can it be due to a blind following of one point of view to the exclusion of all other considerations?

II

The whole story is a long one, but in this connection consideration will be limited to conditioning—its genesis, significance and implications. It is the great Russian physiologist, Ivan Pavlov, who is generally credited with being the originator of the conditioned reflex technique of experimentation. His contributions were received in medical circles with the greatest interest for three decades. It is he who uncovered, for example, the facts which gave the world the illuminating diagnosis of *nervous indigestion*.

Yet Pavlov, since he was the large-caliber sort of man, freely handed the credit to an American as the first to use objective methods such as he was putting into service in 1904 in his study of animal learning. He referred of course to the classic work of E. L. Thorndike, of Teachers College, New York, on "Animal Intelligence," published in 1898. Thorndike's method was to observe and record the objective behavior responses of the animal as it learned, and also to record the situation responsible for calling forth the response. This technique supplied the famous S-R formula, which has since proved so useful in all studies of learning.

Such a study had to be objective and free from introspection on the part of the subject, for one can not very well ask a cat to report upon its mental states when learning. One must rather observe and record its behavior as a chemist observes and records the behavior of the contents of his test-tube.

Meanwhile in 1904 Pavlov began his work in the study of digestion and ran upon some behavior which appeared to be psychological which he could study to advantage by his objective, highly specialized methods. Pavlov emphasized the fact that if salivation is to occur, the *organism* must always be in a state of *readiness* for such a response. The animal must be hungry, and he must be alert. A dog that was satiated or one that was sleepy would fail to respond or to learn. In other words, the condition of the organism which made the response as well as the external stimulus must be duly considered as a factor determining the learning.

Also a principle of general and fundamental significance appeared to be in

evidence, namely, that any arbitrary stimulus might be made to call forth the given response, provided it were presented simultaneously with, or slightly antecedent to the natural (unconditioned) stimulus. The smell of the food and the sight of the food occur repeatedly along with the presence of the food in the mouth, and all phases of the feeding event become intermingled as undistinguishable parts of the total feeding situation. A part thereafter may act as a sign of the whole. This theory, then, Pavlov proceeded to test. Supposing a bell were rung just before feeding the dog, and this were repeated many times, would the arbitrary stimulus (dinner bell) become thereafter by itself an adequate stimulus to start salivation? The answer turned out to be positive. The dog did salivate at the ringing of the bell. Now surely one is well started in the use of technique well adapted for the objective, scientific study of digestive behavior, including factors which are psychological in character. For when a puppy, as a result of learning, has reached the point where he sniffs different objects, rejects the stone and snaps up the bone, is not his behavior at least in part psychological? Hence Pavlov became enthusiastic as to the possibilities of studying psychological phenomena as well as physiological behavior by the use of his newly developed technique.

To be sure, the general principle involved was not new. From Aristotle down, students of psychology have expatiated upon the principle of association. It had long been known even to psychologists that if one rings a dinner bell habitually just previous to the presentation of an appetizing dinner, the subject is likely to learn to associate the one with the other and to respond to the sound of the bell, a purely arbitrary stimulus to be sure, by coming to dinner with his mouth watering. This new technique, however, gave promise of revealing the operation of factors far more precisely than before, by more adequate control of both stimuli and responses, so that the learning process might be revealed with greater certainty and in greater detail. In the hands of Pavlov and his associates, who gave note to the dog as well as to the stimuli presented to him, the technique of conditioning has been productive of excellent results.

What, then, are the net gains to be derived from the use of this new technique as applied to human learning? Much depends upon one's definition of conditioning, if he insists that all learning is conditioning. In the hands of the ultrascientific behaviorists, as we shall see later, it has been trimmed down to mean formation of a new S–R connection such as bell-salivation, by repeated presentation of the arbitrary stimulus (bell), just before, or simultaneous with, a naturally adequate stimulus (food). In this interpretation consideration is restricted to the stimulus and the response, with no reference to the condition of the organism, the mental state of the learner or the effect of the response upon the mental state. *Objectivity is secured not by adding to the objective data, but by discarding all subjective data.* It is as though a physician were to say to a patient entering his office after swallowing a dose of poison: "Now don't try to influence me in my diagnosis by anything subjective. I am much too scientific to be influenced by any so-called ideas you may think you have in what used to be thought of as your mind. I depend exclusively upon objective evidence. I x-ray your bones, record graphically the behavior of your heart, etc., etc., and by the day after to-morrow I shall even have a chemical analysis of the contents of your stomach!"

With regard to consciousness, it is apparent that salivation is a simple physiological response more or less independent of conscious control. One does not turn the salivary secretion on or off as he is presumed to turn the water in the bath

tub on or off at will. In the case, then, of the dog which learns to salivate at the sound of the dinner bell, is the learning of the purely physiological sort and, as such, quite independent of consciousness? The mechanistic psychologist answers in the affirmative.

III

The founder of mechanistic behaviorism was a young man with the wanderlust who had become discontented in the old psychological homestead. As he saw it he was expected to use two very different tools in his work. He found himself saddled with the old introspective tool so elaborately specialized in the hands of Titchener, that tyrannical master trained in the land of the Hitler clan. This tool was used in part in the laboratories carrying on the experimental psychology characteristic of the period.

His first find, which was enthusiastically used, was the S–R tool recently forged by Thorndike. This seemed to be the only usable instrument available about the year 1906 for work in the newly plowed field of animal psychology. Cattell, Thorndike, Bryan and Harter in America, Binet in France, Ebbinghaus in Germany and a large number of others in different countries had demonstrated how subjective and objective methods might be used harmoniously and to the great advantage of results to be gained by each. And they had developed a psychology that was as objective as one well could wish—without throwing out the baby with the bath. However, the second great find of the youthful adventurer was the C–R formula of Pavlov. It was a major invention of the enterprising experimenter to gather it in and trim it to the needs of a brand-new psychology. Not only was the S–R formula of Thorndike to be radically changed to that of C–R, but other changes even more profound were in store for the new science-to-be. For one thing it appeared that the C–R formula, having to do with physiological reflexes, such as salivation in Pavlov's dog, could be considered without inquiring into the animal's consciousness at all. Why not, then, discard consideration of consciousness altogether, discard the subjective element and by reason of this discard have a new science as objective and scientific as physics or chemistry? Great is the promise of the discard! For all one had to do to get the response to the substitute stimulus was to present said stimulus just before feeding the dog. What comfortable learning for the schoolboy! The stimulus takes care of the learning, and the boy doesn't need to know what is going on or even to be conscious at all.

The general statement of the fundamental law of all learning in terms of conditioning is that when a new stimulus (bell) is presented along with or immediately preceding the unconditioned stimulus (food), a new S–R connection is formed. After a sufficient number of repetitions the sound of the bell will by itself call forth the flow of saliva. It would seem to be like the case of school learning in which by simultaneous presentation with repetitions, the stimulus *Columbus* has come to call forth the response *1492*. Yet there is a disconcerting discrepancy between the two sets of data. If the bell is rung many times by itself after the connection *bell-salivation* has been formed, the connection is weakened rapidly and soon disappears. Does this mean that exercise of a new connection weakens it instead of strengthening it? This appears to be in exact contradiction to the fundamental law of exercise accepted by mechanistic psychologists as the sole factor which accounts for establishing a connection. The elementary teacher would surely be disconcerted if she were informed that she must on no account have the learner repeat the stimulus *Columbus,* if she wishes to establish the newly formed connection *Columbus—1492,* since by doing so she would surely eliminate the connection

she has just taken pains to establish. The matter is intelligible, however, if one takes into consideration the *effect* of the response. The teacher is not afraid of repeating the stimulus 3×4 in order to get it well connected with the response 12, provided that response gives a satisfying effect. But if upon repeated trials the ringing of the dinner bell no longer turns out to be a true signal of satisfying food, why should one continue to respond as if it were a sign of food? Surely that would be stupid behavior. When one learns that the bell signal no longer means food, he had better cease salivating and find out what it does signify. What could be more stupid than to keep on acting irrespective of the effect of his action? It is worthy of special note that in the attempt to frame laws of learning to the exclusion of all consciousness, the essential factors of all learning, namely, the readiness of the organism for the response and the effect of the action upon further response, are entirely omitted. Is human learning to be considered without reference to either its purpose or its results?

In view of such considerations, then, is one to harbor a degree of confidence in these "laws" somewhat comparable to that heretofore reposed in the Newtonian laws of motion, because they are presumed to be founded upon evidence which is objective to a like degree? Or do such formulations rather illustrate the difficulties in which one finds himself entangled when he tries to exclude the mental from a study of human life? The behaviorist may well take a lesson from Pavlov on this point. Was it merely a youthful lapse of consciousness to overlook the fact that Pavlov's dog had to be alert—a sleepy dog would not do—and also *ready* with a hunger drive if the learning was to take place? Alertness and motivation would seem to indicate consciousness. Or was consciousness consciously and maliciously done away with to make it possible to trim Pavlov's formula to fit the needs of the new inventions now in prospect?

The brave adventurer was a bit cautious at first in dealing with the matter of consciousness. He tried merely ignoring the troublesome thing. Then, since fortune favors the brave, he decided to deny that there is such a thing and see what happened. Fortune still favored the brave, but things hadn't yet reached the final stage.

Next came the great invention. It was no less than this, to wit, that the only objective, scientific, dependable psychology began in 1912 "when the behaviorist first raised his head," and that all other psychology, past, present or future, must be forever thrown into the discard. This is one of the greatest—probably *the* greatest—of the psychological inventions of the present century if not of all time. One could thereafter look down from the dizzy heights and see the glories of a new era. As stated in one of the leading London papers in reviewing the new book on "Behaviorism":

> He claims to put forward not only a new psychology, not merely a new body of psychological theory, but a system which will in his opinion revolutionize ethics, religion, psycho-analysis—in fact all the mental and moral sciences.

A New York paper comments: "One stands for an instant blinded by a great hope."

Presumably the conclusions arrived at by the new (?) technique of experimentation are to be counted upon as nothing short of the final unadulterated truth. Why bother with speculative philosophy any more?

The behaviorist at length summoned up enough bravado to try a denial of consciousness altogether and stand by for a moment to see what would happen. Nothing happened, except that the new doctrine was accepted and taught to many students in college classes. Those accepting the new doctrine boldly assaulted consciousness at opportune mo-

ments, and built up barricades as best they could to withstand counter attacks upon unconsciousness. But having undertaken to oust consciousness, the trouble was that all the near relatives of that elusive body had to be ejected too. One can't very well banish consciousness and still harbor insight, understanding, purposes, incentives, emotional states of mind and last but not least, the *effect* of past behavior upon future responses. This left only the monotonous law of exercise, the drudge of the classic trio. But it was the only thing to do. Surgery has its place, and sometimes one must pay no heed to where or how much it hurts. To be sure, this makes a sorry plight for the little red schoolhouse with its serious old-fashioned attempt to secure practical purposive results. For, in school, understanding is considered essential, and also the readiness of the learner through adequate motivation. The teacher attempts to control the process by reason of the effects produced. Imagine teaching arithmetic with no life activity to motivate the learning and no resulting satisfaction as the effect of its successful completion.

And so the final stage, mechanistic behaviorism, was finally reached by a series of assaults, consolidations and retreats. For, like Caesar in his Gallic wars, the behaviorist sometimes found it expedient to betake himself as speedily as possible to the fortifications of camp. For example, at one stage it appeared that the ousting of consciousness and of the method of introspection necessitated the exclusion of all verbal report. But it was finally decided that verbal report was too valuable an ally to be dispensed with. Accordingly verbal report was retained as being essentially behavior, and free from any trace of consciousness, insight or effect upon conduct!

Taking a new citadel is like taking on a new line of in-laws or grabbing a bear by the tail. One never knows what it is going to get him in for. However, one has to make at least some show of loyalty and consistency. The behaviorists must surely be given credit for one thing. They have shown good old bulldog tenacity in defense of the unfortunate allies which they got themselves jockied into defending. One just can not but admire their hardihood and their persistence. Some of them, to be sure, rather soon saw the hopelessness of their new positions and scattered somewhat, without appearing to beat too precipitous a retreat. Many of them found purposive behavior too precious to be abandoned. Rugged fundamentalists the pure mechanists assuredly have proved themselves to be. They have discarded the upper story and, in fact, everything above the rock-bottom foundations. The positions still maintained may be enumerated tentatively and in part as follows:

(1) Denial of consciousness and exclusion of all its implications. "Belief in the existence of consciousness goes back to the ancient days of superstition and magic."

(2) Consequent exclusion of the introspective method, in which the experimenter admits for evaluation the *testimony* of the subject. The behaviorist on the contrary records and interprets the *verbal report* of the subject, since this is behavior.

(3) Denial of motivation or *readiness* of the organism as having any bearing upon the response that is made by it, and affirmation that it is the stimulus which is responsible for the action which ensues.

(4) Consequent denial of the *effect* of an action as having anything to do with influencing future actions.

(5) Denial of everything mental, and consequent affirmation that man is a physical mechanism without consciousness—a robot—whose actions are inevitably and absolutely determined by the stimuli with which he happens to be confronted, and by the conditioning that resulted from the influence of stimuli with which he has been confronted previously.

IV

What, then, shall one say of the central theme under consideration, that consciousness, mind, human experience are mere delusions and that human life is the rôle of a mechanistic robot? What

are the alternative views? One is the vitalistic theory, that there is something in man independent of his physical organism, which accounts for his "spontaneous" acts, his "self-activity" or "free will" or whatever one cares to call it. This sounds like an assumption of the immaterial soul of a really bygone pre-scientific age, long since abandoned by scientific workers. Strange to say, the mechanistic psychologists would appear to believe that this is the only alternative to the acceptance of their "scientific" view. But is it? Is one conscious now as he reads this page? A professor not infrequently has in his lecture room a few persons with sufficient confidence in the orthodoxy of what is likely to be said, to be willing to drop off into unconsciousness and leave the lecturer a free field. But in that case the professor has been known to be so revengeful as to put the points learned while asleep on the next written test. This is very likely to confirm the view that consciousness has something to do with learning. One may be willing to admit that he has never experienced the consciousness of any one but himself, and nevertheless be most assuredly aware of his own consciousness. Also, by inference he may believe it extremely probable that most other people have consciousness—of a sort—as well as he. They act as though they did. It is difficult or impossible to find a substitute explanation of their behavior which fits the facts as well as the theory that they are conscious persons too.

As for the other facts and inferences of the physical sciences which seem so sure to the mechanists, one could never learn them, understand them or even think of them if he were unconscious at the time. Is not one's consciousness, one's state of mind, the one and only thing that can be known directly? Everything else is inference dependent upon this primeval phenomenon.

If, then, the fact of consciousness be accepted as a reality, and the physical world including man be also accepted as a reality, do we not have on our hands the age-old mind-body problem? If man is a physical organism responding to physical stimuli, how can he also be a free agent with a mind? One is tempted to dodge the issue, of course. But it is not a satisfactory means of escape from a tiger to shut one's eyes to the tiger. When one sees the burglar entering the bedroom, he may call it an illusory dream if he wants to, and prove it by quoting the mechanistic experts who are sure that all consciousness is a delusion—if indeed there is such a phenomenon at all. But that proof is of little value next morning when one's partner finds the jewelry missing. And for that matter even the hard-headed scientist turns practical philosopher in his off-guard moments when he is a mere man instead of a scientist. He adopts the theory and the behavior that work best to save the jewelry, scientific theory to the contrary notwithstanding. And it would appear that this practical behavior of the uncouth anthropos is by some chance not out of harmony with the modern mode in philosophy called pragmatism. Maybe one shouldn't let trade secrets out of the bag. A doctor must write his prescription in Latin, you know. But at any rate when translated from philosophical jargon into English the root idea of pragmatic philosophy seems to be that the truth of a theory is tested by how well it works. In the case of the burglar incident, doubtless many an individual will continue to take his consciousness of the presence of the burglar seriously, and also the consciousness of those nearest and dearest to him, as to the loss of the jewelry.

In any case it is fortunate for man in the raw that this is a democratic country and that it is the majority vote that carries the day. However, the majority

will have no objection to the mechanist playing his little game all by himself with his consciousness submerged or repressed, though that would seem to us crude folk to be a psychological depression worse than the recent economic one.

But to return to the point at issue—to be conscious or not to be conscious: that is the question. Whether it is smarter in the fight for fame to face things as they are in the hard practical world—to take arms against a sea of problems and by reflection solve them. Why not lose consciousness in peaceful sleep? To sleep! And by a sleep to say we end the head-aches and the thousand awkward knots psychology is heir to. 'Tis a consummation devoutly to be wished. But in that sleep of peace what nightmare might emerge! Ay, there's the rub should give us pause, and bid us rather face the facts we have than fly to tangles that we know not of.

Consistency makes drudges of us all. And oft the resolution pales. But hist! What fine invention's this! I'll change the name of action and call it pure behavior! I'll be the first behaviorist and start another *ism!*

Now Fortune's headed rough
And damned be he who first dares call my bluff!

V

Seeing that some one must take up the psychologist's burden, how shall one account for consciousness? Surely not in terms of a resident vitalistic principle, alias immaterial soul. That would raise the still more disturbing nightmare as to where it exists, what sort of thing it is, and how it could harmonize with the fact that the nervous system and body as a whole correlate so closely with the individuality of the person, with the functioning one finds it so convenient to designate as mind. There surely is no evidence of mind apart from a functioning nervous system. Mind and brain are phases of the same reality. One may lose a leg and substitute a wooden leg for it without seriously interfering with the quality of his intellect. But it is a different story if anything seriously disturbing happens to the nervous system. A wooden head, unless obtained by inheritance, does not work at all. Even when inherited it is nothing to brag about. May one not be on speaking terms with both a brain and consciousness?

Again, who is to give one the final word as to just what electricity is and what it is not? Is it the shock one receives when he comes within a circuit? Is it a flash of light? Is it a form of energy? Or should one consider only the physical structure, the dynamo, and some one phase of its "physical behavior" and deny the reality of all other "apparent" manifestations? May it not be that one form of manifestation has as much claim to reality as another, provided consideration of it may prove useful in a life situation?

As to mind, consciousness, human experience, these seem most appropriately considered as aspects of a functioning nervous system in a living organism, just as an electric current is aptly interpreted as a part or phase of the functioning of an electric dynamo. Why deny either the current or the dynamo or the power by which the electric train is propelled? And in psychology what is to be gained by denying mind or consciousness? Let those who wish specialize on this aspect of behavior, while others concentrate on the physical aspects of behavior, such as the action of muscles and glands. Every man to his trade. Live and let live. There is no call for warfare. It is unnecessary to assume that all physical structures must function in the same way.

As to whether there can be any such thing as spontaneity of action, any degree of choice or volition, I quote from Gerard:

> Evidence now on hand has established the fact that the nerve itself generates or actively propagates the impulse, as a fuse passes on a spark. The nerve is active, not passive. In the same way the central nervous system must now be looked upon as composed of active units continually in play and which are modified rather than set in motion by particular types of stimuli.[1]

This affords a physiological basis for Froebel's assumption of self-activity on the part of the child, a concept which seemed to add greatly to the vitality of the educational philosophy of his time. How about the activity of the heart? That beats incessantly from before birth to the end of the three-score-and-ten period. But this action is not credited with being under voluntary control. It exemplifies physiological activity rather than mental activity. Its center of control is beneath the functional center of the organism as a whole, topographically as well as functionally.

How about breathing? One can take a deep breath "voluntarily," but one can not commit suicide by holding his breath. Breathing is not under voluntary control to that extent. How about running a hundred yards in ten seconds or writing a scientific treatise on geology? The sprinting is well within the range of freedom of an organism such as that of a Jesse Owens, but beyond that of most of us. Similarly with regard to writing the treatise on geology. Such functioning is forever beyond the bounds of volition of an idiot. In the case of certain persons it could become possible with sufficient training. In any case it appears that the bounds of "volition" and "choice" are decidedly restricted. No scientist of today would defend a large degree of human freedom.

But there is no philosophic problem of more far-reaching significance than that as to whether there is at least some small degree of human freedom, as opposed to one hundred per cent. mechanistic determinism. With little or no determinism there could be no stability, no prediction, no science. All would be chaos. On the other hand, if there were absolute mechanistic determinism there could be no such thing as human responsibility, and therefore no significance in human life.

What part of the organism is responsible for the voluntary aspect of behavior, if such there be? A common answer characteristic of the gestalt school is that one thinks with his whole body. But this statement is likely to be misleading. One who has just broken his leg thinks *of* his leg but not *with* his leg. To quote again from Gerard:

> The nerve cells, then, can spontaneously discharge impulses but normally do not do so because they are dominated by a more active region. . . . Even at "rest" there is an active equilibrium—some cells discharging, some beating electrically, others held quiet; by the play upon them of nerve impulses, field potentials, blood chemicals and other still unknown means of integration. . . . Such a dynamic concept of activity of the nervous system gives us also a possibility of explaining other phenomena, now well established, but inexplicable along more orthodox lines. Some of these are: *the unitary stream of consciousness*. . . .

VI

Finally a word is called for as to that most outlandish of all claims of the extreme mechanist, that the *effect* of an act has no influence upon future acts. If experimental evidence is desired on this point, one may consult the recent publications of the Institute of Educational Research of Teachers College, New York City. It is a poor fish that must keep on forever biting the same hook that gives him nothing but a pain, assuming that

> Lacking the sense to run away,
> He lives to bite another day.

Surely the mechanists do not mean to slam *homo sapiens* so severely as this. Sometimes, to be sure, there is evidence of stupidity a-plenty, but on the other hand there are also indications of intelli-

[1] R. W. Gerard, Scientific Monthly, January, 1937, p. 51.

gence, of profiting from the effects of past experience.

What is it that scientists are really after in their supposed search for truth? Is it not essentially the *consequences* of the various factors under consideration? What, for example, are the *effects* of exposure to the typhoid bacillus, the effects of vaccination? Effects, relationships, consequences—these seem to be the goals of the search for truth. And it is the truth that gives one that degree of freedom and control which it is possible to achieve. Freedom is a matter of ability to avoid certain effects and to substitute other effects, made possible through knowledge of relationships between factors and their effects. Professor John Dewey has emphasized the need of regard for consequences. To disregard effects, consequences, surely this is the behavior of an undisciplined child. Only the foolish, the witless, the thoughtless, disregard the consequences. Foresight implies prediction of probable after-effects, and foresight is the part of wisdom as opposed to folly.

Some may consider it unjustifiable to bring the philosopher into the discussion. Is the scientist right when he gives vent to the belief that the philosopher is only a speculator, a brain-truster, not one who by use of the modern methods of research arrives at the final truth? Scientific methods should yield reliable truth, but unreliable people will play with scientific methods. Philosophers, too, continue to survive, and Darwin, who was something of a scientist in his day, considered that survival was to the credit of the survivor, in that it had something to do with fitness.

But what is the difference between the scientist and the philosopher? Both profess to be in search of truth. In general, is it not the function of the philosopher to look at things in the large? He does not detach things from their connections. He emphasizes relativity, relationships, synthesis. He strives to take in the whole, fit all the parts together with none of the parts left out, and each part fitted into its appropriate place so as to make a consistent whole. If he were in an automobile plant, he would be an assembly man. Such work is surely important, for what does it profit a man to know all about a carburetor if there is no one to fit the carburetor into its place so that the car will go?

And what is the special function of the scientist? Is he not for the most part a specialist on parts? The behaviorist, for example, specializes on the more specific forms of behavior, such as reflex responses. Sometimes one is tempted to remind him that possibly the best salivator may not turn out to be the keenest intellect, or that the behavior of rats in a maze may at times be somewhat different from that of humans in a fog. Also one is tempted to remind him that it is not always wise to be too dictatorial even if one has absolute confidence that the principle upon which he is depending is correct. One is reminded of the motorist who went straight ahead, oblivious to all other considerations, because he was sure that he had the right of way. He arrived at his final destination many years ahead of time, and is still oblivious to all irrelevant points of view, even including his precious right of way!

Is it safe to depend exclusively upon one point of view? Is it safe to consider the part and be oblivious to its relation to the whole? Is not this the part of narrowness and the particular sin one is prone to charge up to the account of the fundamentalist? It is no easy task to try to see all the parts in their relation to the whole, but such is the goal of the philosopher; and philosophy, synthesis, appreciation of significant broad relationships must be a part of every science which would hope to apply its contributions to the life of man as a whole. There are, moreover, trade demarkations. A psychologist may respect the field and func-

tion of the philosopher without muscling in on his territory or excluding him from the union. The analyst had best learn to work in harmony with the synthesist or else agree to stick to his own trade.

VII

As a means to this end, it would seem that the prodigal had now gone far enough to see the error of his ways and that he should be almost ready to return to the old homestead. He struck off when quite young, with a laudable ambition to explore the world without the restricting influences of his elders. So far, so good. But he fell upon evil times. First he lost his mind, as earlier historians have recorded. "Then he lost consciousness, but still retained behavior—of a sort." The behavior, however, was by no means adequate, being confined mostly to the cruder reflexes and the like. In short, the organism was largely defunct. It responded to nothing but external stimuli and was paralyzed from the neck up. Having lost consciousness, the poor fellow was seriously disoriented. He had become entirely oblivious to the complexity of normal human behavior and of the many factors accounting for it, such as the readiness of the organism, the constitutional differences in organisms from the outset, the subleties of the configurations in which the stimuli might have their settings, the effects of past behavior and such like.

These symptoms will doubtless suggest the diagnosis as that of advanced paresis, though occasional flashes of involuntary insight and of detached emotional responses might seem to cloud the picture somewhat and rather to suggest dementia praecox, especially in view of the youth of the victim at the initial stages of the onset of the disorder.

Be that as it may, it is surely high time for the prodigal to come home. He will be welcomed back to the family fireside. The effects will be most satisfying to all concerned. One hesitates to mention the matter of conditions of his return. The home can well afford to be magnanimous. There will surely be more freedom than in the unbelievably restricted sphere of action depicted above. Of course the veil had to be drawn over certain details. But it is to be hoped that the son and partial heir will not in future ignore the *effects* and consequences of his behavior, nor ever again pawn or discard his mind, which is believed by many to be one of the most valuable possessions bequeathed by inheritance from a long line of ancestors. And also it is to be hoped that, if there ever should hereafter be a temporary lapse from the path of rectitude, it would turn out to be only a temporary debauch falling far short of a total loss of consciousness with all the dangers which this loss implies. These admonitions are intended in all kindness. They are the outcome of the wisdom of the ages of psychological accumulation from Aristotle down.

The return might be suitably celebrated by killing the emotional complexes that have tended to block the free scope of the intellect. The freedom thereby enhanced would surely contribute to peace and prosperity for all members of the psychological family, now grown so large and so divergent in family traits.

The return might change the mode of thinking somewhat for a few, but then the modes change anyway, as there has been occasion to note, from causes not wholly logical even in matters believed to be quite highly intellectual. Peace without victory! How may this be secured? Surely this is one of the great unsolved psychological problems. It deserves consideration in the not too distant future.

HOW WE SPEND OUR TIME AND WHAT WE SPEND IT FOR

By EDWARD L. THORNDIKE

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I HAVE been at some pains to collect available statistics on how people now and in times past have spent their time. The results are rather meager. Indeed it is not certain that my estimates for men and women of this country are more accurate than those which Dr. Nissen made at my request for chimpanzees! He writes:

There is probably considerable variability in how a chimpanzee spends the day in his native habitat. Especially important is the age of the animal; sex, season, composition of the group, geographical locality and food supply, I think are also factors. My estimates, which in part at least are pretty wild guesses, are based largely on experiences during the dry season in French Guinea.

	Adolescent	Adult
Sleep (in a nest at night)	11 hours	11 hours
Resting (on ground during day)	2 "	4 or 5 "
Eating activities (includes climbing around in trees, picking fruit, peeling and shelling; intermittent rest) / Productive labor (travelling towards sources of food, water, nesting sites, avoidance of enemies; building nests)	6 "	6 "
Social and individual play, fighting, sex courtship, auto- and hetero-grooming	5 "	3 or 2 "

A very different distribution would be found for nursing mothers.

There are a number of reports concerning the time schedules of students, but their case is too special to use except as a supplement. The best data concerning adults are those given under fifty-nine rubrics by Nelson[1] for a large group (nearly 500) connected with a Y. W. C. A. The study made in 1931 was repeated in 1932. From Nelson's records I compute that 48 hours a week are used to get a living (including time of transportation to and from work), 56 hours for sleep and 3½ hours for responsibilities to the home where one lives. Twenty-four hours are spent in eating, personal care and shopping. The remaining 36½ hours include: church activities, 1½; outdoor games and sports, 3¼; automobile rides and trips, 4½; reading, including the newspaper, 7; studies and lectures, 1–; movies, theater, pageants, 3¾; sedentary games, 1¾; music, 1¾ (seven eighths of which is passive listening); radio other than music, 1–; sewing, painting, arts and crafts, 1–; parties, dances, picnics, club activities, dates with men and entertaining in the home, 9.

We may summarize the expenditures of waking hours as 48 to productive labor, 6 or less to other duties, 33½ or more to pleasure, 24 to eating, personal care and shopping, and ½ unspecified. If the 24 hours are credited half to keeping the person alive, well and presentable for her work and half to the pleasures of the palate, of sociability and of gaining the approval of others and of oneself by one's appearance, the total for work and duties is 66, not quite three fifths of waking time; and that for pleasure is 45½+, somewhat over two fifths. Of course, some of the productive labor and going to and from it may be pleasurable also.

Moralists generally, and the liberal reformers of the nineteenth century in

[1] "Leisure-Time Intervals and Activities of Business Girls," 1934.

particular, seem to have expected that if people were enabled to obtain the necessities of life with a part of their time and energy, they would use a large fraction of the balance in the pursuit of learning, wisdom, beauty and good works. The fraction is small in these business girls. Except for the newspaper, the average reading is about 3½ hours a week, studies and lectures are less than 1 hour, and even an optimistic evaluation of the concerts, club activities, etc., would probably not sum to an hour that would have been approved by Bentham or either Mill (or for that matter, by Carlyle or Ruskin or Matthew Arnold or Cardinal Newman). Yet this group is probably much superior to the average of the population and had convenient and free access (in New York City) to science, literature and art. They had the time and were obviously not exhausted by their labors, since they resorted to resting other than sleep for less than one hour per week.

A benevolent and intelligent trustee for the welfare of these young women should move rather cautiously in the direction of increasing the amount of their pure pleasure time. It may be better for them and for all concerned (1) to improve the health of the individuals, (2) to improve the quality of the home so that the 40 odd hours spent there in eating, dressing, reading and housework are more enjoyable, and (3) to improve the quality of the office or shop so that the 42 hours spent in productive labor are more enjoyable.

Before commenting further on the facts, let us try to translate the schedule of time spent (except in sleep or at productive labor for a wage) into a schedule of wants gratified. For example, how should the hour and a half spent in church activities be allotted among the desires for security, for the approval of others, for self-approval, for the welfare of others, for mental activity, for social entertainment and for the pleasures of sight and sound? How should the 10

TABLE 1

THE PERCENTAGES OF THE TIME SPENT IN VARIOUS ITEMS OF ACTIVITY BY BUSINESS GIRLS WHICH GRATIFIED CERTAIN WANTS, ACCORDING TO A JURY OF PSYCHOLOGISTS

	Personal care	Home responsibilities	Automobile	Talking with family	Writing letters	Reading the newspaper	Church activities	Sum for 55 items, all except sleep, work, and transportation to and from work
1. Protection against hunger, cold, heat and wet, animals, diseases, and bad people, exercise, rest and sex relief	10.8	15.5	9.7		0.1	4.0	4.0	20.2
2. Avoidance or reduction of pain	3.2	1.9	3.0		0.1	0.8	1.1	2.1
3. Pleasures of taste, smell, sight and sound	5.8	10.5	16.1	2.8		8.3	6.9	14.3
4. Mental activity, curiosity and exploration		0.3	6.7	5.9	11.6	58.3	3.6	8.1
5. Manipulation and construction	0.8		1.6		0.1			1.0
6. Security (other than in 1)	3.8	10.5	0.3	9.3	4.7	1.7	17.4	1.5
7. Affection (to get it)	14.1	3.7	3.5	14.8	15.1		3.6	4.7
8. Companionship	5.3	4.1	12.6	29.6	18.3	5.8	16.7	8.5
9. Approval from others	19.6	16.3	3.5	2.8	11.1	2.5	7.3	7.3
10. Approval from one's self	14.2	9.2	0.3	1.9	5.3	5.3	5.8	4.3
11. Mastery over others	5.3	1.7	0.8	3.7	3.3	0.8	1.1	1.9
12. The welfare of others	0.5	10.2	0.8	9.3	9.7	1.7	7.3	1.9
13. Sex entertainment	11.4	8.5	15.9	0.9	16.7	2.5	5.8	11.5
14. Social entertainment	3.0	6.1	24.2	17.6	3.5	3.3	16.7	10.5
15. Physical entertainment	1.1	0.7	0.8		0.1			1.5
16. Unspecified comfort	0.8	0.7	0.3	0.9		4.2	2.9	0.7

hours for personal care be allotted? How should the $3\frac{1}{2}$ hours for home responsibilities be allotted?

Table 1 shows the allotments in the case of samples from the 55 items according to a jury of six psychologists and also the summation of the allotments of all the 55 items reporting time spent other than in sleep, work for wages and transportation to and from work.

In so far as the jury's allotments are dependable, the time other than that spent in sleep, work for a wage, and transportation to and from work serves chiefly the desire for entertainment in a broad sense. Including the allotments to sensory pleasures of taste, smell, sight and sound, and half of those to mental activity, curiosity, exploration, manipulation and construction, 42 per cent. of such time is so spent, about 20 per cent. being spent for physical needs, about 12 per cent. being spent to get approval and about 13 per cent. to get companionship and affection. The results by any reasonable allotments would not differ greatly from these.

Records like these from business girls are not available for business men, farmers, factory workers, housewives or any large adult groups. We have to rely on general observation helped out by various facts of record.

The hours of sleep for adults 20 to 60 may be set at 8 per day or a bit more. The amount of mere rest (*i.e.*, rest without any accompanying entertainment) is probably under half an hour per day. In the business girls it was an eighth of an hour. In reports by professional, sales and factory workers (male and female) of a telephone company, less than 2 per cent. of leisure time was credited to mere rest. The amounts would presumably be larger for persons doing hard muscular work, but they are a small and declining minority; and few even among them are too tired to enjoy the radio.

In ordinary economic conditions the average number of hours of work for wages or about the home, including time spent in going to and from work, is probably not far from 50 per week or 7 per day for adult men and women. The variation is of course enormous, probably from zero to a hundred, as suggested by Masters's poem.

In the hives of all the cities, high above
The smoke and noise, where the air is pure,
Are numberless widows, comfortable and secure,
Protected by the watchman and God's love;
Saved by the Church, and by the lawyer served,
And by the actor, dancer, novelist amused.
Some practise poetry; some, who are younger nerved,
Dabble in sculpture; but all are used
To win the attention of celebrities
At dinners, or at the opera, to imbibe
The high vitality of purchased devotees.
But when not modeling, or scribbling verse,
Nor drinking tea, nor tottering forth to dine,
They sit concocting some new bribe
To life for soul relief; they count what's in their purse;
They stare the window half asleep from wine
Or poppy juice; they wait the luncheon hour;

. . . .

And in the city there are numberless women,
Widows grown old and lame, who scrub, or wait
On entrance doors, or cook; whose lonely fate
Is part of the city's pageant, part of the human
Necessity, victims of profligate
Or unprevisioned life! They have no spoil,
No dividends, and no power of subsidy
Over the world of care and poverty;
They have but patience and a little room,
Patience and the withered hands of toil.[2]

The farmer's work is a balance of the seasons; the soft-coal miners have tried for years to get 200 days of work per year; the retail dealer and his clerks may work far beyond union hours; many houseworkers add the care of their own homes to eight or more hours for wages. But these great variations are consistent with even greater uniformities. In ordinary times most workers in factories, retail and wholesale stores, railroad and utility companies, schools, the civil ser-

[2] Edgar Lee Masters, "Poems of People," D. Appleton-Century Co., N. Y., 1936; pp. 120, 121, 122 (Widows).

vices, banks, insurance companies, hotels, restaurants and households have regular jobs with regular hours of work and regular duties at home, summing, as stated, to nearly fifty per week.

The care of the body and personal appearance may be estimated at 5 hours a week for men and 8 for women. Routine eating takes perhaps 10 for men and 8 for women (the difference in time being spent by the women in serving and cleaning up, counted in their work records).

About 40 hours a week are left at the adult's disposal. He is free to use these to gratify any of our wants—for security, affection, companionship, approval (of himself, his fellow-men, or his God), power over things or people, the welfare of others, intellectual activity and achievement or entertainment of whatever sort we choose. I shall make a provisional estimate of how they are used by allotting the schedules of leisure time activities reported by professional, sales, and factory employees of a large telephone company to the wants they seem to serve. I shall be guided by the judgments of a jury of psychologists.

For example, games, sports and other forms of exercise (including sailing, hunting and fishing, but excluding gardening) account for 12.8 per cent., 16 per cent., and 21 per cent. of the leisure time reported by professional, sales and factory men, and for 7.6 per cent., 9.3 per cent. and 21.8 per cent. of that reported by professional, sales and factory women, respectively. I allot time so spent as follows:

to the desire for physical, and also sensory, intellectual, sex and social entertainment	76 per cent.
to the desire for companionship	10 " "
to the desire for approval	6 " "
to other wants	8 " "

Playing cards and other sedentary games account for 7.6 per cent., 4.6 per cent., 4.5 per cent., 5.2 per cent., 5.6 per cent. and 2.7 per cent. in six groups, in the order MP, MS, MT, WP, WS and WF (M = men, W = women, P = professional, S = sales, F = factory). I allot 65 per cent. to entertainment of all sorts, 15 per cent. to companionship, 8 per cent. to approval, 5 per cent. to the enjoyment of power and 7 per cent. to all other wants.

Parties, dancing, conversation and other social gatherings account for 5.5 per cent., 13.4 per cent., 8.2 per cent., 13.3 per cent., 11.4 per cent. and 12.7 per cent. in the six groups. I allot 60 per cent. to entertainment, 25 per cent. to companionship, 5 per cent. to affection, 5 per cent. to approval and 5 per cent. to all other.

The radio, movies, talkies, theater and vaudeville account for 7.2 per cent., 23.3 per cent., 18.5 per cent., 10.4 per cent., 23.1 per cent. and 17.2 per cent. of the time reported by MP, MS, MF, WP, WS and WF, respectively. I allot 80 per cent. to entertainment, 10 per cent. to companionship and 10 per cent. to all other wants.

Reading accounts for 32.7 per cent., 31.5 per cent., 19.2 per cent., 35.6 per cent., 31.2 per cent. and 18.3 per cent. in the six groups in order. I allot 60 per cent. to entertainment, 9 per cent. to approval from others, 7 per cent. to self-approval, 20 per cent. to intellectual cravings which are too useful, fine or noble to be rated as the desire for mere pleasure or entertainment and 4 per cent. to all other wants.

So far we have about three quarters of the leisure time of these adults accounted for, with the desire for entertainment far in the lead and the desires for companionship and approval at the head of the others.

I have considered that 70 per cent. of automobiling ministers to entertainment directly or indirectly, and 15 per cent. to companionship, and 15 per cent. to all

other wants.[3] Time spent in making music and listening to music (other than radio) is assigned 80 per cent. to entertainment, 10 per cent. to approval and 10 per cent. to all other. Gardening time is assigned 50 per cent. to entertainment, 20 per cent. to approval, 20 per cent. to the welfare of others and 10 per cent. to all other.

Allotting the times stated by the percentages stated we have the estimates of Table 2.

Evidence of the use of leisure time for the welfare of others is rare, except in the case of the professional men. They report 9.2 per cent. of the time as "with family or children." In the other five groups (in order) this figure is 0 per cent., 2.0 per cent., 1.4 per cent., 1.6 per cent. and 0. The other evidence is in the time spent in clubs more or less concerned with social betterment. The percentages are 3.3, 0.3, 3.4, 4.3, 0.6 and 1.4. The reports for religious activities give 1.7 per cent., 0, 0, 1.5 per cent., 1.6 per cent. and 2.5 per cent. The reports for lectures and studies give 1.4 per cent., 6.3 per cent., 5.0 per cent., 4.4 per cent., 4.3 per cent. and 5.8 per cent. The reports for sewing give 0, 0, 0, 0.5, 1.9 and 8.3 per cent.

Some of the times for family, clubs, church, lectures and studies and sewing should be allotted to entertainment, but we may use this as a factor of safety for the conclusion that over half of the free time of adults in this country, or about 25 hours a week, is spent for entertainment. Another large fraction is spent for companionship, which is itself in part a form of entertainment.

The radio, the talkies, the automobile and the popular magazines are ready providers. They do not, however, completely fill the bill, since, by nature or training or both, people demand companionship, sociability and a chance to talk, and favor a certain amount of physical activity. The family circle and the social gathering are not and probably never will be outmoded as sources of enjoyment (certainly not the latter). They maintain their appeal; a friendly group engaged together without compulsion in almost any sort of activity will entertain itself.

The amount of time spent in physical entertainment by means of games and sports has probably increased also within the past generation. But the enormous increase has been in reading magazines, riding in automobiles, going to the pictures and listening to the radio. The time saved from wage-work and family work by reductions in hours and by gas, electricity, household appliances has gone for increased entertainment, supplied mostly by these four means.

Some students of history and sociology will credit the present flood of entertain-

TABLE 2

ALLOTMENTS OF LEISURE TIME FOR PROFESSIONAL, SALES AND FACTORY EMPLOYEES OF A LARGE COMPANY

	Professional		Sales		Factory	
	Men	Women	Men	Women	Men	Women
Percentage of leisure time reported as spent in games and sports, social gatherings and conversation, radio, theatre, movies and talkies, reading, music, automobiling, and gardening..	76.0	80.9	89.8	85.2	87.2	78.0
Allotted to entertainment	49.2	52.3	61.4	58.3	59.6	54.8
Allotted to companionship	5.0	6.5	9.3	7.2	7.6	7.9
Allotted to approval	8.2	7.7	7.1	6.9	6.9	5.4

[3] If it were the use of money to buy the car instead of the use of time for riding in it, the desire for the approval of others would count heavily.

ment to the great increase in the supply coupled with commercial methods of stimulating the demand. They will argue that men will, under fit environmental conditions, spend their free time in serving the state by fighting or otherwise or in serving the church by religious rites or in serving the family by labor and ceremonial. They will assert that men will follow true gods of truth or beauty or virtue or utility or the common good as readily as the false god of entertainment if they are shown the right path by example and have their feet set upon it by habit.

I hope that this is so. But I fear that the craving for entertainment is deeply rooted in man's nature and that very strong counter-attractions will be required to stem the present flood. I prophesy that historical and anthropological research will increasingly reveal that the great majority of people have spent their free time for entertainment up to or beyond thirty hours a week, if a supply was available. The desire for approval may counteract it widely, as in waves of Puritanism or patriotism. Also, the desire to see others happy, which apparently has been held down by brutal and bigoted customs in most civilizations, may become a more and more potent alternative, at least in superior souls. The human nervous system is very adaptable and can learn to operate with satisfaction in a humdrum world. But its lines of least resistance go toward cheerful sociability, free play, sensory stimulation and emotional excitement.

SOME MEXICAN IDOLOS IN FOLKLORE

By Dr. ELSIE CLEWS PARSONS
NEW YORK, N. Y.

EVER since an English gentleman named Septimus Crow "discovered" Lake Chapala in the state of Jalisco, Mexico, and built its first villa where he entertained German merchants from Guadalajara, American railroad men and Porfirio Diaz, there has been at this little lakeside resort a traffic in the *ídolos* which have been washed up from the lake or dug up in the hills back of the town, in ancient Indian cemeteries, or faked by the townspeople. An English lady who visited Chapala thirty-nine years ago quotes Mr. Crow as saying that the *ídolos* sold Lumholtz were faked, information that the somewhat malicious Mr. Crow did not impart to the ethnologist. I do not know what Lumholtz did with his collection, but about this time Frederick Starr also made a collection of the miniature pottery water jars, figurines, etc., which came from the waters of the lake, and this collection is in the Peabody Museum at Cambridge. This collection is not faked. Starr published a careful description of the collection,[1] but beyond giving some comparative notes on miniature offerings made elsewhere in Mexico he gives little or no account of the way the Chapala Lake offerings may have been made.

Miniature pottery vessels were offered by the ancient Aztecs,[2] Tlascalans[3] and Zapotecs[4] in their mountain shrines as prayer-images. These miniatures are also being found on Monte Albán so the ancient Mistecans may also have offered prayer-images of this type. Some of the modern Zapotecs, also the Mixe, still offer them, the Zapotecs calling them *pedimentos,* requests, for what they are praying for. The people of Mitla and nearby towns make their "requests" from the stones of the fields New Year's eve when they visit the miraculous cross which probably marks the site of an ancient temple; the mountain people of Yalálag make theirs of pottery and deposit them in a stone shrine on a mountain pass during their pilgrimage on the fourth Friday of Lent. I think the miniatures from Lake Chapala were similar prayer-images.

All the Chapala offerings are either perforated or of a form to which string could be tied. They may have been hung on a stick, a prayer-stick, just as the Huichol Indians hang their miniature prayer-images to-day. The Huichol and Cora who live in the mountains of Nayarit, northwest of Chapala, are reputed to have come from the east, possibly as refugees at the time of the Conquest. They have many traits in common with the Pueblo Indians to the north and with the ancient Aztecs, and among these traits figure prayer-sticks or arrows and miniature ritual objects.

Among the Chapala miniatures are animal figurines, some of an animal I do not identify, others are unmistakably figurines of a dog. The dog figurine that I had on my table at Chapala was plainly a faked one—it had never been under the ground or in the water; but why had the maker modeled the dog just that way, with something in its mouth and some-

1 "The Little Pottery Objects of Lake Chapala, Mexico," *Bulletin* II, Department of Anthropology, University of Chicago. 1897.

2 Fray Bernardino de Sahagún, "A History of Ancient Mexico," 134. Tr. by Fanny R. Bandelier. 1932.

3 F. Starr, "Notes upon the Ethnography of Southern Mexico," *Proceedings of the Davenport Academy of Sciences,* VIII, 117, 1899–1900.

4 E. C. Parsons, "Mitla, Town of the Souls," Index, Prayer-image. University of Chicago Publications in Anthropology. 1936.

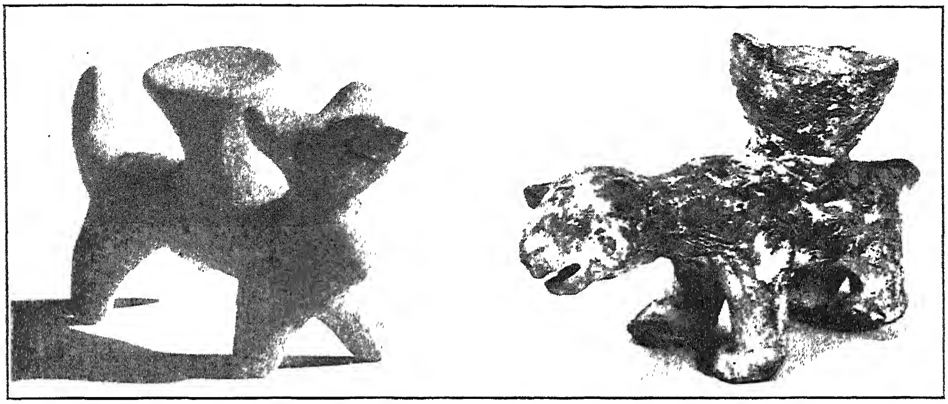


FIG. 1. DOG FIGURINES
Left. FIGURINE FROM CHAPALA, JALISCO. *Right.* FIGURINE FROM CHIAPAS. LENGTH, 5 IN. PEABODY MUSEUM, HARVARD UNIVERSITY.

thing on its back? Nobody knew. Then one day as I was inquiring into the belief about the dog that carries people over the river of death, an ancient and modern belief[5] both among the Aztecs and the Zapotecs, and one that is held also by the Chapala townspeople, the secret of the dog figurine was revealed. The dog is being well fed and he stands ready with a burden basket on his back to swim a passenger across the water (Fig. 1).

The dog ferryman belief is that if you treat dogs well a dog will carry you across the big river you have to cross in your journey after death, a river sometimes identified with the River Jordan, but if

[5] The Lacandones of Chiapas in southern Mexico may have had the same belief, for at each corner of a grave is placed a small palm-leaf figure of a dog; and a clay figurine (Fig. 2) collected by Dr. Tozzer ("A Comparative Study of the Mayas and Lacandones," 47, 91, Pl. XIX, Fig. 1), resembles the Chapala figurine.

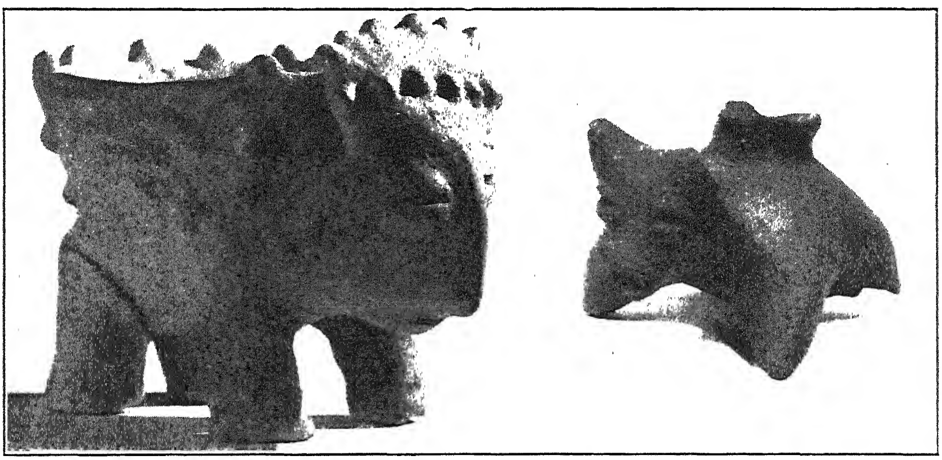


FIG. 2. FIGURINES FROM JALISCO
Left. COLLECTED AT CHAPALA, IN 1934. *Right.* COLLECTED IN 1884. PEABODY MUSEUM.

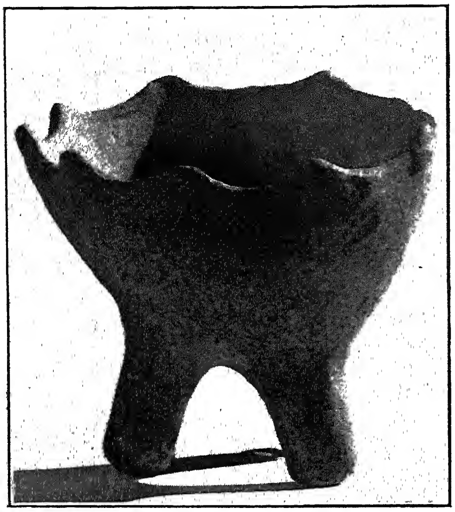


FIG. 3. TRIPOD
COLLECTED IN CHAPALA. AMERICAN MUSEUM OF NATURAL HISTORY

you have maltreated dogs, beating them or refusing them food, you will be left stranded on the bank of the river. The river dogs are black for an Indian, add the Zapotecs, and white for a Spaniard; white dogs will not carry an Indian lest they soil their coats—unless you have a piece of soap with you and promise to wash your ferryman on the other side. The burden or carrying basket of the Chapala Lake region, the ancient basket carried in the ancient way, by tumpline, is the exact shape of the object on the back of the dog figurine, narrow and deep and flaring toward the top.

FIG. 4. FIGURINE OF HARVESTER
COLLECTED IN CHAPALA. AMERICAN MUSEUM OF NATURAL HISTORY.

In identifying another type of basket I was less fortunate. This is the basket carried by the creature both the ancient and the modern peoples call nagual. Among the Zapotecs and the southern peoples[6] nagual is a kind of guardian spirit secured to a child at birth by sprinkling ashes outside the house and observing the tracks made in the ashes the night of the birth—tracks of lion or of some other animal, of a snake or bird, or marks of lightning. Lightning or Lion becomes the nagual of the child and will aid him throughout life. Among the Tlascalans nagual was a night pilfering spirit,[7] and this is the conception of nagual held to-day at Lake Chapala, where more specifically it is believed that the nagual is a person transformed in part into an animal who enters a house with a basket to pilfer corn, beans or whatever is available. Fig. 2 expresses the tradition, representing a basket carried on the back of a four-legged, human or partly human faced creature. The Aztecs and the Quiché believed that shamans had the power to transform into animals; the early Spaniards also believed that witches could effect this transformation. The present-day Chapala belief[8] may be a fusion of Indian and Spanish beliefs.

[6] Compare the Quiché of Guatemala. Oliver LaFarge II and Douglas Byers, "The Year Bearer's People," 133–135. Middle American Research Series, Pub. 3. Tulane University, 1931; Mitla, 225–227.

[7] Starr, "Southern Mexico," VIII, 122.

[8] Compare the story of a woman who turns coyote to steal a lamb recorded in Nahuatl from Milpa Alta, D. F., by Dr. Boas (*Journal of American Folk-Lore*, 37: 360–362, 1924).

Circular, shallow baskets are in use to-day, but they are not scalloped like the brims in Fig. 2 (left) and Fig. 3. Sometimes these modern baskets are left unfinished, *i.e.*, without a binding around the brim and the splints give the baskets a pointed appearance. Possibly these points are represented in the clay models, of which there are a large number of modern copies in Chapala.

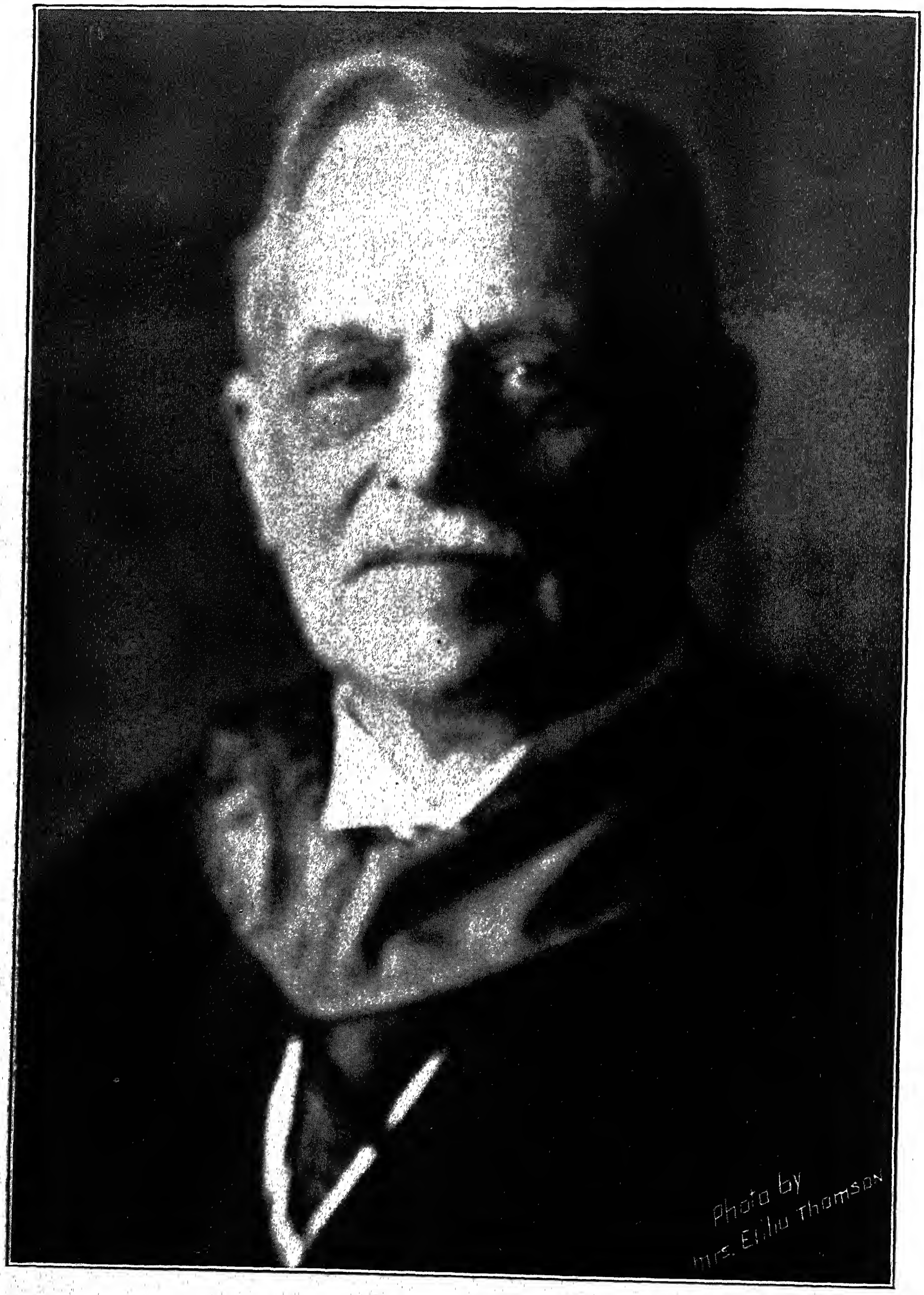
The animal figurine supporting a bowl which has a wide-spread distribution in Mexico has been found as near Chapala as Colima. A similar type of figurine may have been the model for the modern potter (compare Fig. 2 (right)), who merely emphasized human features in the animal head.

Although in this general region ancient pottery is distinguished by its representation of incidents of daily life, in Fig. 4 the modern potter has probably presented an entirely original design, that of the harvester on his knees, singing an *alabanza* or praise song, before he puts the crop into his basket. It is customary for the harvesters to make a circle around the pile of corn ears and to sing the song they call *álalavado*, the same song that is sung at midnight at the wake for the dead. It begins:

Cristo en cruz cruci—
Ficado
Que por me
Está este suerte.

"It is a long, sad song"; two persons sing, the others present joining in a refrain.

The modern potter of Chapala, the faker, whoever he is, is a clever craftsman. Unfortunately, it was impossible to meet him; he sells his wares through agents, as anonymity is essential to his market.



ELIHU THOMSON

THE PROGRESS OF SCIENCE

ELIHU THOMSON

Elihu Thomson, internationally noted inventor, engineer, researcher and teacher, was born at Manchester, England, on March 29, 1853. His parents were Daniel and Mary A. (Rhodes) Thomson. His father, a skilled mechanical engineer, was of Scotch descent, and his mother was English, of French Huguenot descent. In 1858 the family removed to America, settling in Philadelphia, Pa., when Elihu was five years old. In the public schools of Philadelphia Elihu as a child manifested inherited aptitude for mechanics and science, graduating from grammar school at the age of eleven years, sufficiently advanced in his studies to enter high school. But, as the entrance age for that school was thirteen, and the school officers considered Elihu unduly precocious, they advised setting his studies aside for two years. However, the boy was so unhappy without books that his mother provided him with elementary scientific literature and he began scientific experimenting and invention that continued unbroken throughout his life.

Young Thomson entered the Central High School of Philadelphia, at thirteen, where Dr. Edwin J. Houston, who was professor of natural philosophy, became greatly interested in his outstanding pupil; this attachment continued for life, the two men being subsequently in engineering partnership. When Thomson graduated from the high school in 1870, he continued at the school as instructor, and in 1875 became professor of chemistry and mechanics. During this period he lectured on electricity at the Franklin Institute in Philadelphia. In 1875 he built his first model dynamo, following this by other dynamo machines for arc lights in series, one of which was exhibited in 1877 at the Franklin Institute.

In conjunction with Professor Houston he invented a machine for the continuous centrifugal separation of substances of different densities, which, being particularly applicable to the separation of cream from milk, has come into extensive use in creameries. This was one of the first inventions connected with the name of Thomson to receive a U. S. patent, which patents during his life numbered over 700. In the winter of 1877–78 he served with Professor Houston in a committee of the Franklin Institute on dynamo-electric machines, and tests reported by them established a milestone in the art of dynamo-electric testing in this country. The following year Thomson and Houston developed a complete arc lighting system embodying many unique and ingenious features.

In 1882 the Thomson-Houston Electric Company was founded, with Professor Thomson as chief engineer and inventor. He then put into practical operation a number of electrical inventions that had been developed during his teaching period in Philadelphia. In 1883 the factories of the Thomson-Houston Company were moved to Lynn, Mass., where was initiated a period of phenomenal development in electrical engineering, extending from arc lighting to incandescent lighting, motors, transformers, distribution and electric railways.

Outstanding among the Thomson inventions was electric welding by the resistance method (patented in 1886). This has become more and more extensively applied in metal manufacturing industries. An invention of primary importance in electrical distribution was the Thomson integrating watt-hour meter, first exhibited in 1890 and applicable both to direct- and alternating-current circuits. It received half of the first prize in the Paris Electric Meter Competition of 1890. As is well known, it consists of a little electric motor, taking its small driving power from the electric circuit and recording upon a

dial in kilowatt hours the amount of energy delivered. Others had attempted to produce such a motor meter, but without success until Thomson employed a commutator of very small diameter with bars of pure silver and with silver brushes resting thereon.

Another invention of great practical importance was his magnetic blow-out for extinguishing arcs at switches and lightning protectors, by the mechanical force of a magnetic field in the immediate neighborhood of the arc. He contributed to the design and construction of internal combustion engines and improved the construction of turbo-ship propulsion and of electric railways.

After 1892, when the Thomson-Houston Company was merged with the Edison General Electric Company and others into the General Electric Company, Professor Thomson was associated with this great company as inventor, and consultant in engineering matters, patent litigation and general questions of policy. He was founder and director of the Thomson Research Laboratories.

Professor Thomson was recognized as one of those who have contributed most to the development of electrical science in the past fifty years. He was awarded the following medals: John Scott Medal of the City of Philadelphia; Franklin Medal of the Franklin Institute; Elliott Cresson Medal of the Franklin Institute; Rumford Medal of the American Academy of Arts and Sciences; John Fritz Medal of the American Engineering Societies; the first Edison Medal of the American Institute of Electrical Engineers; Hughes Medal of the Royal Society of Great Britain; Kelvin Medal of the British Engineering Societies; Faraday Medal of the Institution of Electrical Engineers, London; Grashof Medal of the Verein Deutscher Ingenieure. In addition he received the Grand Prix at the Paris Expositions of 1889 and 1900; the Chevalier and Officier crosses of the French Legion of Honor. His honorary degrees were bestowed as follows: A.M., Yale University, 1890; Ph.D., Tufts College, 1894; D.Sc., Harvard University, 1909; LL.D., University of Pennsylvania, 1924; D.Sc., University of Manchester (England), 1924.

Professor Thomson was a fellow of the American Association for the Advancement of Science, the American Institute of Electrical Engineers, of which he was president in 1889–90, the American Chemical Society, the American Philosophical Society, the American Academy of Arts and Sciences and the National Academy of Sciences. He was a member of the Institution of Civil Engineers of Great Britain, an honorary member of the Franklin Institute and of the Institution of Electrical Engineers of Great Britain. For many years he was a member of the corporation of the Massachusetts Institute of Technology, of which he was acting president in 1921–24. He was one of the six official U. S. delegates to the chamber of delegates of the Electrical Congress in Chicago in 1893; president of the International Electrical Congress in St. Louis in 1904, and succeeded Lord Kelvin as president of the International Electrotechnical Commission in 1908, serving for three years.

Personally he had the simplicity of manner which often marks the man of high attainments. He was an excellent speaker, and his lectures were remarkable for their directness and lucidity. He was married on May 1, 1884, to Mary L., daughter of Charles Peck, of New Britain, Conn., by whom he had four sons, three of whom survive him. Mrs. Thomson died in 1916. He was married on January 4, 1923, to Clarissa, daughter of Theodore F. Hovey, of Boston, Mass.

His death occurred on March 13, 1937, bringing to a close a long and remarkable career which greatly advanced the application of science to the world in which we live. Elihu Thomson will long be remembered as a great leader in American electrical engineering.

ARTHUR E. KENNELLY

SYMPOSIUM ON THE LIFE AND WORK OF RENÉ DESCARTES: CELEBRATING THE TERCENTENARY OF THE PUBLICATION OF HIS "LA GEOMETRIE"

THE publication in 1637 of Descartes' "La Géométrie," founding what is now known as analytic geometry, was one of the greatest events in the history of science and mathematics. For that single work did more than any other to emancipate the mathematical spirit from the 2000-years dominion of Euclid and thereby made possible the subsequent great mathematical developments that now constitute what is perhaps the chief intellectual glory of the modern world.

It was to signalize fittingly the immense importance of that seventeenth century deed of emancipation that *Scripta Mathematica* arranged the symposium on the achievements of the great emancipator, René Descartes (1596–1650), which was held on March 18 in the Horace Mann Auditorium of Teachers College, Columbia University. The meeting, attended by about 600 specially invited guests, was honored by the presence of a representative of the French Embassy in Washington.

Descartes' astounding versatility en-

DISCOURS

DE LA METHODE

Pour bien conduire ſa raiſon, & chercher

la verité dans les ſciences.

PLUS

LA DIOPTRIQVE.

LES METEORES.

ET

LA GEOMETRIE.

Qui ſont des eſſais de cete METHODE.

A LEYDE

De l'Imprimerie de IAN MAIRE.

cIↃ IↃ c xxxvII.

Avec Privilege.

FACSIMILE OF THE "DISCOURS DE LA METHODE" PUBLISHED IN 1637

abled and led him to do memorable research in a wide variety of fields. Hence the desirability of providing a symposium of speakers, each specially qualified to deal with one or another of the various fields.

The speakers and their themes were as follows: "The Mathematical Contemporaries of Descartes," by Professor David Eugene Smith; "Descartes as Mathematician," by Professor Edward Kasner; "Method and Vision in Descartes' Philosophy," by Professor William Pepperell Montague; "Descartes as Scientist," by Professor Frederick Barry; and "Descartes as Physiologist," by Professor Horatio B. Williams.

In the near future *Scripta Mathematica* will publish the several addresses in full. Here it is possible to do no more than to indicate briefly one or two of the cardinal ideas in each of them.

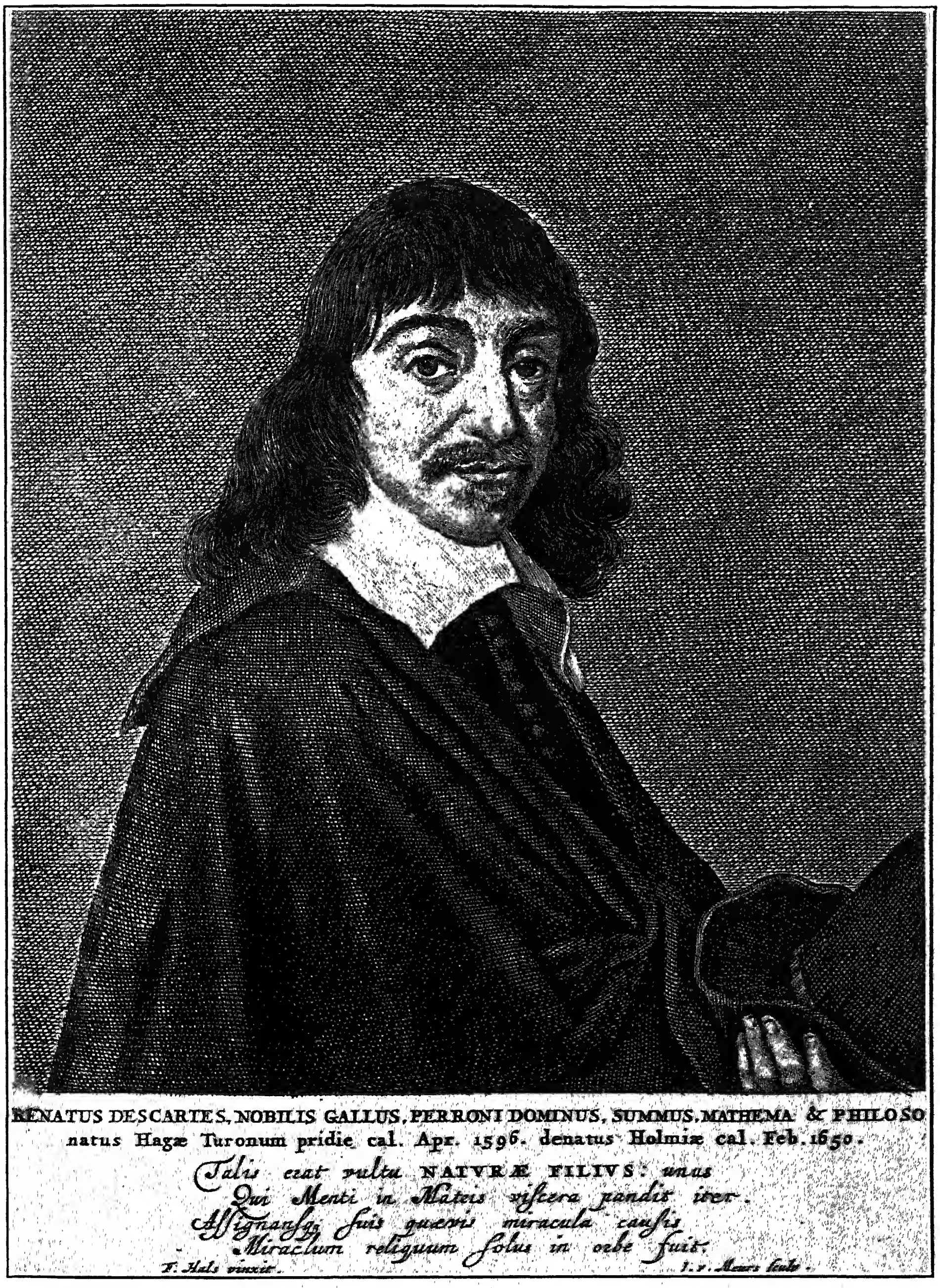
The writer of this note acted as chairman of the meeting. In his introductory remarks he endeavored to give a sense of the social atmosphere or mental climate in which Descartes was bred, lived his life and did his work. That the seventeenth century did probably more than any other both to honor and to dishonor the human spirit was shown by citation of the main characteristic facts of the time: on the one hand, such glorious facts as the prodigious fertility of the century in famous men and great contributions to literature, art, philosophy, medicine, physical science and mathematics; on the other hand, such inglorious facts as the prevalence of superstition, the absence of freedom of thought and speech, the more than continental mania of the Witch Hunt, and the still ghastlier horrors of the Inquisition.

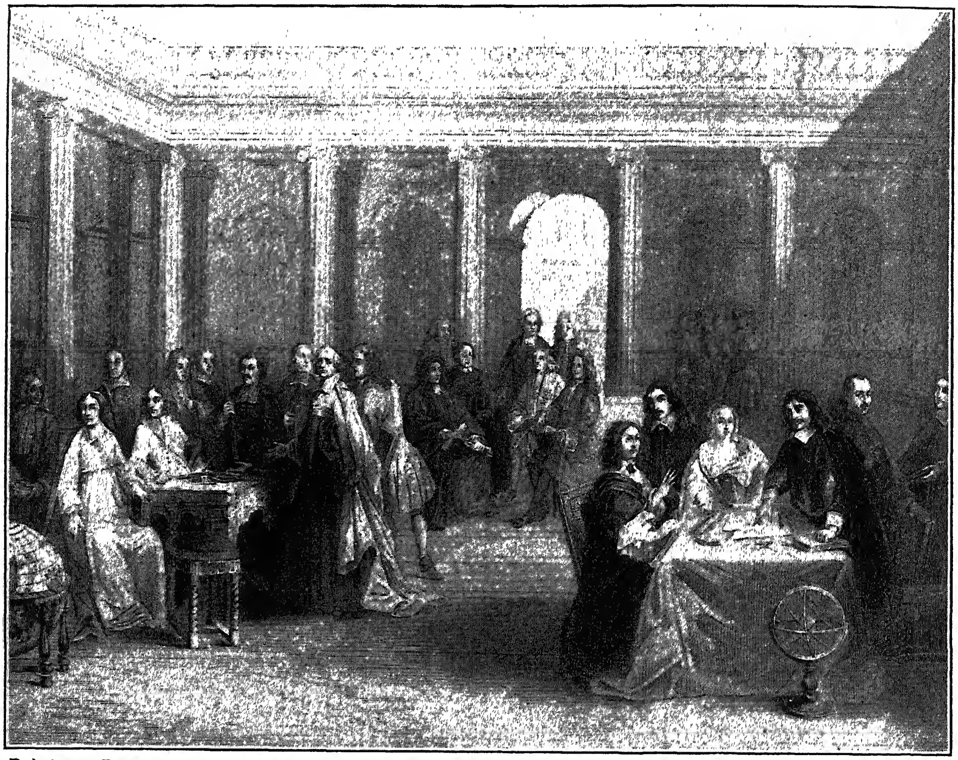
Among Descartes' mathematical contemporaries there were, said Professor Smith, three men who towered above the rest in creative power: (1) Pierre de Fermat, "the greatest genius in the theory of numbers up to his time and possibly of all times"; (2) the engineer Gérard Desargues, "the greatest geometer whom Descartes could have known, the most original of seventeenth century contributors to pure geometry," in fact, the founder of modern projective geometry; and (3) Blaise Pascal, "an infant prodigy who played with geometry as other children with toys, and at the age of sixteen published a famous essay on conics."

Professor Kasner pointed out that Descartes, "the founder of what is now called analytical geometry, never wrote a separate book on mathematics"; that his "La Géométrie," which, said Kasner, "will be eternal," was published, in the interest of philosophy, as only a relatively small part of the author's immense "Discourse on Method"; that "his book on geometry was not merely about geometry," but that in addition to the study of "curves—a very fashionable thing in the seventeenth century—it really contains a lot of algebra, equation theory, and the beginning of the calculus as well."

Descartes' aim, said Professor Montague, was to construct a cosmology having the charm of philosophy and the logical rigor of mathematics. The task's demands were two: (1) a set of axioms, or indubitable truths, to serve as principles; and (2) the deduction from these, in Euclidean fashion, of a true theory of the world. The Cartesian principles were either dubitable or trivial, and their alleged implicates sadly failed to follow logically. But, though Descartes' proofs were poor, his vision was great: a striking confirmation of Professor Montague's thesis that "philosophy is great, but its greatness is a greatness in vision."

"It is hardly possible," explained Professor Barry, "to distinguish Descartes the philosopher from Descartes the scientist." "The cosmology outlined in his 'Le Monde,' subsequently elaborated in


RENATUS DESCARTES, NOBILIS GALLUS, PERRONI DOMINUS, SUMMUS, MATHEMA & PHILOSO
natus Hagæ Turonum pridie cal. Apr. 1596. denatus Holmiæ cal. Feb. 1650.
Talis erat vultu NATVRÆ FILIVS: unus
Qui Menti in Matris viscera pandit iter.
Assignansq; suis quævis miracula causis
Miraclum reliquum solus in orbe fuit.
F. Hals pinxit.
J. v. Meurs sculp.



Peint par Dumesnil *Gravé par Rebel*

QUEEN CHRISTINE OF SWEDEN LISTENING TO A GEOMETRICAL DEMONSTRATION BY DESCARTES

his 'Principles of Philosophy,' served to coordinate all that was then known of the essential nature of things.'' It had, however, one fatal defect as a logically developed system—the concept of *mass* was absent—and had consequently to be rejected as erroneous. ''Descartes' service to theoretical science is undeniable, but the results of his reasoning, owing to defective premises, were superseded by the work of such successors as Huygens and Newton.''

''It has been denied,'' said Professor Williams, ''even by Sir Michael Foster, that Descartes was a physiologist at all, it being alleged that Descartes merely wrote about the subject in connection with his philosophical speculations.'' But Dr. Williams, supported by the authority of Thomas H. Huxley, asserted that Descartes was ''entitled to the rank of a great and original physiologist, an unwearied dissector and observer.'' In support of that judgment Dr. Williams quoted from Descartes a series of propositions ''constituting the foundation and essence of the modern physiology of the nervous system.''

The latest and best account of Descartes' life and great mathematical creation is found in a chapter of Bell's recently published ''Men of Mathematics.'' In connection with the tercentenary celebration the publishers generously gave *Scripta Mathematica* reprints of Bell's account for free distribution. At the meeting it was announced that such a reprint together with a large portrait of Descartes reproduced from Smith's ''Portraits of Eminent Mathematicians'' may be obtained free by writing *Scripta Mathematica*, enclosing six cents for postage.

CASSIUS JACKSON KEYSER

DEAN FRANK CLIFFORD WHITMORE, HONORED BY THE AMERICAN CHEMICAL SOCIETY

Dr. Frank C. Whitmore, dean of the School of Chemistry and Physics of the Pennsylvania State College, has been elected president of the American Chemical Society for the year 1938. On March 5, he was presented with the William H. Nichols Gold Medal by the New York Section of the American Chemical Society in recognition of his researches in molecular rearrangements and the polymerization of olefins.

The Nichols Medal was established in 1902 by the late William H. Nichols to "stimulate original research in chemistry." In the words of the founder, this medal is to be given not solely because of advanced work of a constructive character, but particularly because such work has been made available to all chemists through publication. Among the more recent recipients are James Bryant Conant, president of Harvard University; Henry C. Sherman, Columbia University; Julius A. Nieuwland, University of Notre Dame; and William Mansfield Clark, Johns Hopkins University.

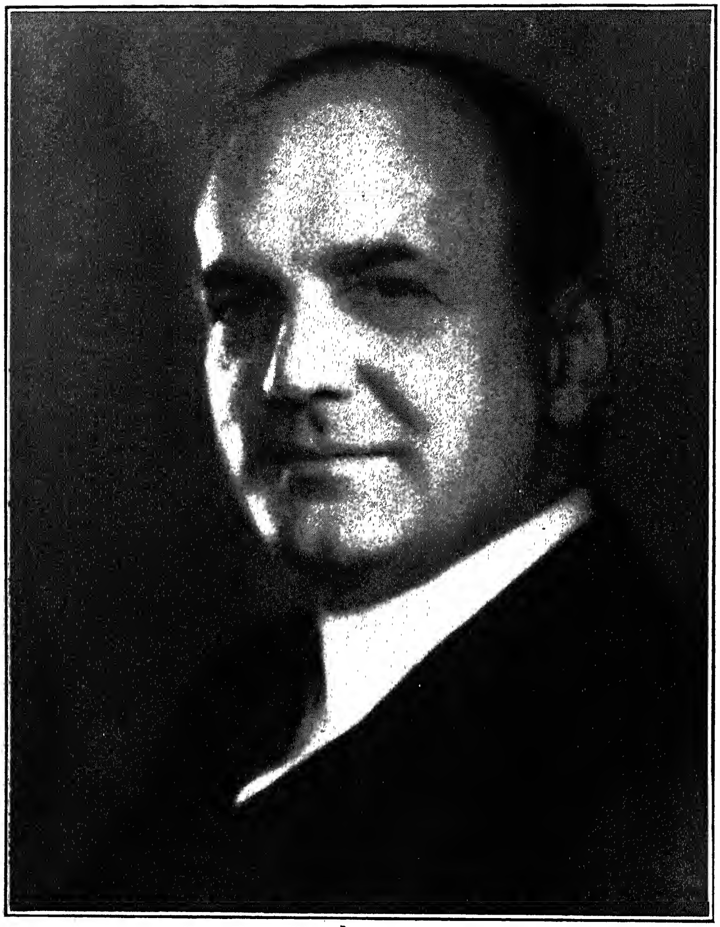
Before the presentation of the medal, Dr. Walter S. Landis, chairman of the Medal Jury of Award, announced that in order to insure perpetuation of the Nichols Medal, a gift of securities had been made to the New York Section of the American Chemical Society by C. W. Nichols, chairman of the board of the Nichols Engineering and Research Corporation and son of William H. Nichols. This generous and timely gift is in the form of securities of the Allied Chemical and Dye Corporation, perpetuating as successor the great industry of which Dr. William H. Nichols was so integral a part.

Dr. Whitmore was born at North Attleboro, Mass., on October 1, 1887. He spent his boyhood in New Jersey and Pennsylvania, and was graduated from the high school at Atlantic City. He was a member of the class of 1911 at Harvard University and received his master's degree there in 1912 and his Ph.D. in organic chemistry in 1914. He was instructor at Williams College during 1916–1917, and at Rice Institute during 1917–1918. In the latter year he was appointed assistant professor of chemistry at the University of Minnesota, and two years later became professor of organic chemistry at Northwestern University. After serving some years as head of the department, he went to the Pennsylvania State College in 1929.

Dr. Whitmore was chairman of Section C of the American Association for the Advancement of Science in 1932, chairman of the Division of Chemistry and Chemical Technology of the National Research Council 1927–1928, has been a director of the American Chemical Society since 1928, and was for eight years secretary and chairman of the Division of Organic Chemistry. In 1931 he was a member of the Council of the International Union of Pure and Applied Chemistry.

He is the author of 103 published research papers, of "Organic Compounds of Mercury" in the series of American Chemical Society Monographs, and his "Advanced Organic Chemistry" has just been published.

Dr. Whitmore's researches were begun under the direction of Professor Charles Loring Jackson and were first concerned with the anomalous reactions of sodium malonic ester. Throughout the years of his teaching at Minnesota and at Northwestern his attention was centered on the organic compounds of mercury. In the last ten years he has made a searching study of aliphatic compounds, including the dehydration of saturated alcohols, the determination of olefins, polymerization reactions and intramolecular rearrangements. His explanation of these rearrangements on an electronic rather



DEAN FRANK CLIFFORD WHITMORE

than an ionic basis has reduced to consistent order a very large number of formerly anomalous reactions.

Dr. Whitmore was one of the first to prepare an organic deuterium compound, neopentyl deuteride. Within the last two years his laboratory has worked with the sterols and sex hormones. His colleague, Professor R. E. Marker, has recently completed the synthesis of the female hormone, oestrone or theelin.

Dean Whitmore's election to the presidency of the American Chemical Society is a tribute not only to his scholarship and to his successful administrative record, but also to the simple, forthright charm that has won him friends in all parts of the country. His vigor, his inherent gaiety and his infectious enthusiasm have inspired work and devotion not only in thousands of students but in all parts of the chemical profession. To him any form of work is fun, and any form of research is grand fun—not the fun of conflict or competition, but the satisfying joy of discovery and creation.

GERALD WENDT

THE FIRST INTERNATIONAL CONFERENCE ON FEVER THERAPY

THE First International Conference on Fever Therapy was held in New York City from March 29 to 31, 1937. For more than a year plans had been formulating under the joint auspices of medical investigators from many countries interested in this new development in physical therapy and eager for the opportunity of exchanging experiences and comparing methods and results.

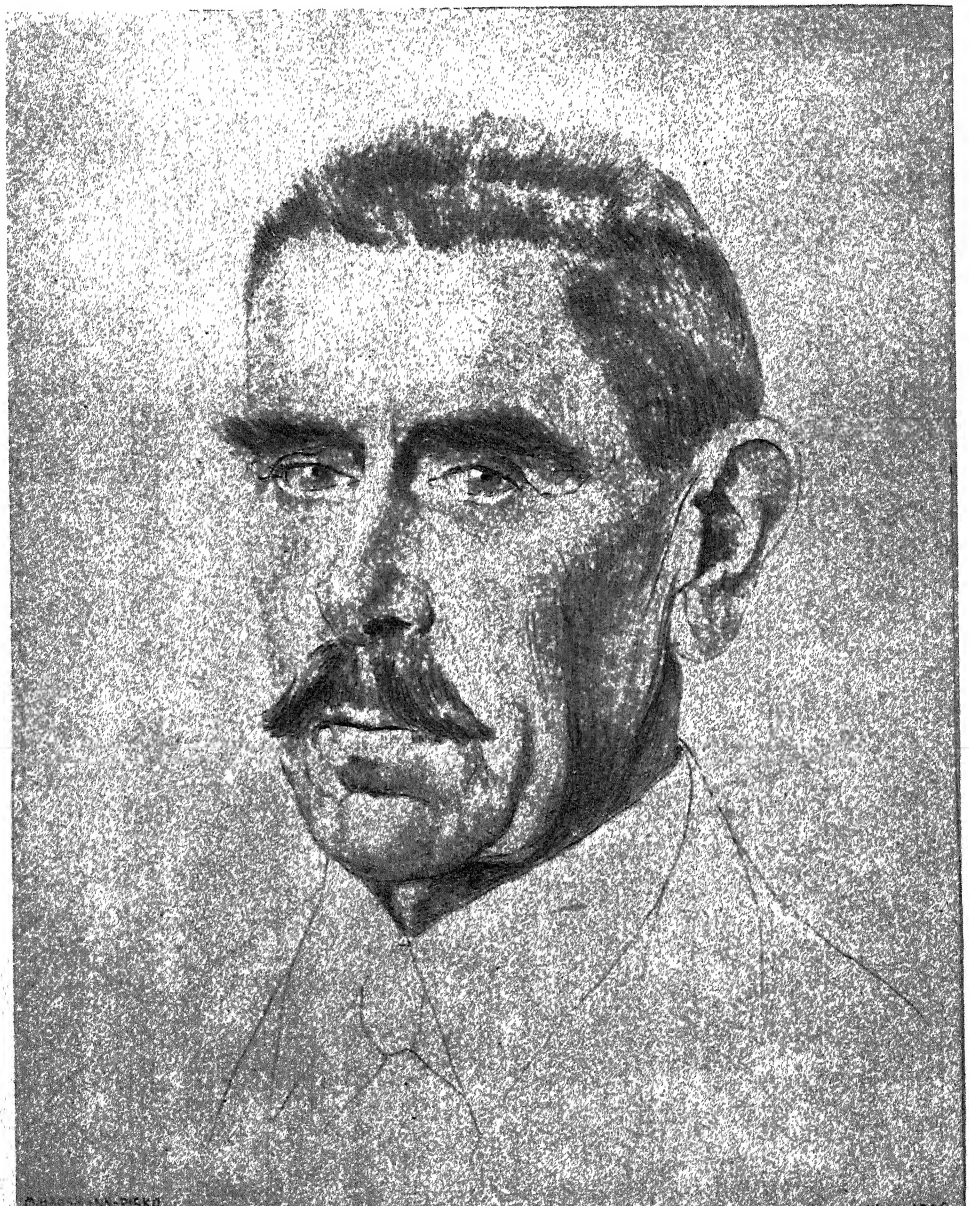
The present research interest and clinical activity in the field of hyperpyrexia date from the remarkably keen observations by Professor Julius von Wagner-Jauregg in Vienna, of remissions which not infrequently followed intercurrent infections in patients with general paresis. His analysis of this phenomenon led to the deduction that artificially induced, controllable fever might be a useful therapeutic agent, rather than a manifestation of disease only to be avoided and combatted. After trials with old tuberculin, vaccines, etc., von Jauregg finally inoculated patients with the plasmodium of malaria, controlling the paroxysms of chills and fever with quinine, as and when necessary. Such spectacular clinical results followed as to bring to him the Nobel Prize Award in medicine in 1927. Since that time this general therapeutic theory has been expanded and extended to a variety of pathologic states, and the fundamental mechanisms affected by fever and in turn potentially instrumental in combatting disease, have been subjected to careful scrutiny and experimental analysis.

It was altogether fitting, therefore, that Professor von Jauregg should have been made honorary chairman of this first international gathering of medical scientists to take inventory of the present status of fever therapy in the world today. The active chairman of the conference was Baron Henri de Rothschild, of Paris, its secretary Dr. William Bierman, of New York City. Official delegates representing their respective ministers of health were sent by Australia, Austria, Belgium, Canada, Chile, Colombia, Denmark, Dominican Republic, Ecuador, England, France, Greece, Mexico, Nicaragua, Salvador and Yugoslavia; representatives were also present from Germany, Brazil, Holland, Hungary, Italy, North Africa, Norway, Poland, Portugal, Roumania, Spain, Sweden, Switzerland, Turkey and Russia; the United States Army, the Navy and the Public Health Service were each represented by official delegates, as were the New York City Departments of Health and of Hospitals.

The first day's sessions were held at the College of Physicians and Surgeons, Columbia University. Professor Pierre Abrami, president of the French committee and professor of medical pathology, University of Paris, replied to the address of welcome extended by Dr. Allen O. Whipple. Messages were read from Professor Julius von Wagner-Jauregg and Professor d'Arsonval.

The scientific papers on the first day dealt with the relative merits of the various methods of inducing fever and the more fundamental underlying physiological, chemical and pathological phenomena which accompany or result from pyretotherapy.

At the very beginning in Professor von Jauregg's message and repeatedly reemphasized throughout the three days of addresses was the necessity for the utilization of every other known specific and non-specific measure *in combination with* fever therapy, if the optimum clinical results are to be obtained in the treatment of the diseases under discussion. Pyretotherapy is not a specific therapeutic procedure even in those diseases where the known etiologic agent is sufficiently thermolabile to be inhibited or killed at human fever levels. Von Jauregg wrote: "For reasons not far to seek, it was thought that the therapeutic process might be due to the high tempera-



PROFESSOR JULIUS VON WAGNER-JAUREGG

ture level observed in malarial treatment. I was quoted as holding this opinion myself, but this is far from correct. As early as 1887 and 1895 I voiced the opinion stating that the high temperature level is nothing but an index for the intensity of a therapeutic process running its course in the organism. Since then I have stressed this view again and again.'' Professor Abrami summarized the present methods in fever therapy as comprising two completely distinct approaches: the one, intrinsic, through the body's own reaction to injected foreign materials of various types, as exemplified in the ''shock'' reactions to peptone, sulphur, vaccines, malaria, etc.—reactions controllable neither as to frequency, intensity or duration, as pointed out by Professor Richet, and, therefore, susceptible of much harm and even death in weakened individuals; the other, extrinsic, in which the body passively responds to physical agents in the environment—electrotherapy, radiotherm or hypertherm—and with which exact dosage is under the immediate and continuous control of the physician. Professor Abrami stated his belief that the uniformly beneficial results reported, following the use of each of these methods, represent the sum of very complex biological reactions, especially important modifications which take place in the functional state of the neurovegetative system. These biological reactions, which are almost always associated with a febrile attack, can sometimes occur in the absence of hyperthermia, with the production of the anticipated therapeutic results; conversely, fever may not be followed invariably by clinical improvement. It was the consensus of opinion among those attending the conference that there is no ''ideal'' single method of fever induction at the present time and probably never will be, because of the individuality of the problem as it presents itself in different diseased states in different patients. In the last analysis personal medical judgment must be exercised, as in every medical problem.

Dr. Hardy, of the Russell Sage Institute, discussed interference with heat loss in the human body as being the chief mechanism through which fever temperatures are attained. The changes in blood volume, acid-base equilibria and especially the chloride balance in artificial fever were presented by Dr. Gibson and his associates from the Harvard Medical School, and by Dr. Stafford Warren, of the Rochester School of Medicine.

The cytologic reactions to fever, induced by the various means already cited, in partial explanation of how fever effects its results, were discussed by Dr. Doan, of Ohio State University's College of Medicine. The lymphoid elements are destroyed and their regeneration inhibited during fever, whereas the bone marrow reacts promptly with new and increased numbers of granulocytes. The phagocytic elements are greatly stimulated irrespective of the method used for inciting the fever reaction. Dr. Hartman, pathologist at the Henry Ford Hospital, Detroit, analyzed the post-mortem findings in fatal instances of hyperpyrexia.

From the clinical view-point the outstanding therapeutic success to date in the application of pyretotherapy to disease has been in gonorrheal infections. A half day's symposium was devoted to the presentation of the scientific and clinical data in this area. When systemic fever therapy is combined with additional local heat, as advocated by Bierman, of New York, and Krusen, of the Mayo Clinic, for periods of time which may be accurately determined for each patient through *in vitro* thermal death time studies of the gonococcus as advocated by Carpenter and his associates at Rochester, N. Y., a complete cure may be accomplished in more than 90 per cent. of the cases. Gonorrheal arthritis, especially, and endocarditis have been successfully treated by fever therapy.

Because of the biologic similarity of the meningococcus to the gonococcus, Dr. Mary Moench, of the Cornell University Medical School, reported *in vitro* studies of fifteen strains. Five were either destroyed or greatly inhibited at 41° C. after five hours, seven showed moderate reduction in growth, and three were not appreciably affected after seven hours. In selected cases, especially septicemias, in which specific serum therapy has failed or can not be used, fever therapy is felt by Dr. Moench to be worthy of trial as an adjunct to other measures.

Another half day was devoted to the experimental and clinical studies in syphilis with fever therapy. The evidence seems to justify the conclusion that artificial fever fortifies and intensifies the curative action of chemotherapeutic agents, both in early visceral and in late neuro-syphilis. Simpson, Neymann and others reported a higher proportion of remissions with a lower mortality rate, using physically induced fever, than have been reported statistically following malaria. The one exception is the report of Dr. Maurice Ducoste, medical chief of the Psychiatric Hospital at Villejuif, France, who introduces the malarial blood intracerebrally. Of 435 patients with general paresis treated in the past ten years 353 or 81 per cent. are reported cured; there were 25 deaths (6 per cent.). Before the introduction of this form of malaria treatment 73 per cent. of the patients of this type died during the first six months and 88 per cent. during the first year in this institution.

A variety of other conditions have been subjected to fever therapy in an attempt to supplement a limited or unsatisfactory therapeutic rationale. Among these are acute rheumatic fever, chorea and acute and chronic infectious arthritis. Simmons and Dunn, from the University of Nebraska, Osborne, Blatt and Neymann, of Chicago, and Barnacle, Ewalt and Ebaugh, of Denver, confirmed the encouraging results reported by Dr. Lucy Porter Sutton and Dr. Katherine Dodge, of New York University, in chorea and rheumatic carditis. Dr. Stecher, from Western Reserve, reported excellent results in acute non-specific arthritis. More time must elapse before a full and complete evaluation can be made of the final place fever will occupy in the treatment of these and other miscellaneous conditions.

It must be emphasized that much remains to be learned with respect to the indications and the contraindications for artificial fever therapy as applied to human disease. It is a therapeutic procedure which should be rigidly limited at the present time to hospital or institutional administration under trained medical and nursing supervision, where every means is available for meeting the emergencies which occasionally arise. Much encouragement may be derived, however, from the cordial and frank exchange of ideas and experiences which the conference just concluded provided, and in the knowledge that medical investigators the world over are pooling their resources to bring to diseased individuals safely and promptly these new therapeutic measures.

The Government of France through the Ambassador at Washington and the Consul-General in New York officially recognized the contributions of American investigators to the field of fever therapy by conferring the cross of the Legion of Honor on Messrs. Kettering and Whitney and Drs. Bierman and Simpson during the conference. The modern spirit of collaboration of engineer and physician, of physicist and biologist, in the conquest of disease has been unusually clearly and splendidly shown throughout the writing of the American chapter in the development of physical therapy.

CHARLES A. DOAN, M.D.,
Secretary, Section on Physiology and Pathology

THE SCIENTIFIC MONTHLY

JUNE, 1937

CHEVREUL AS PSYCHOLOGIST

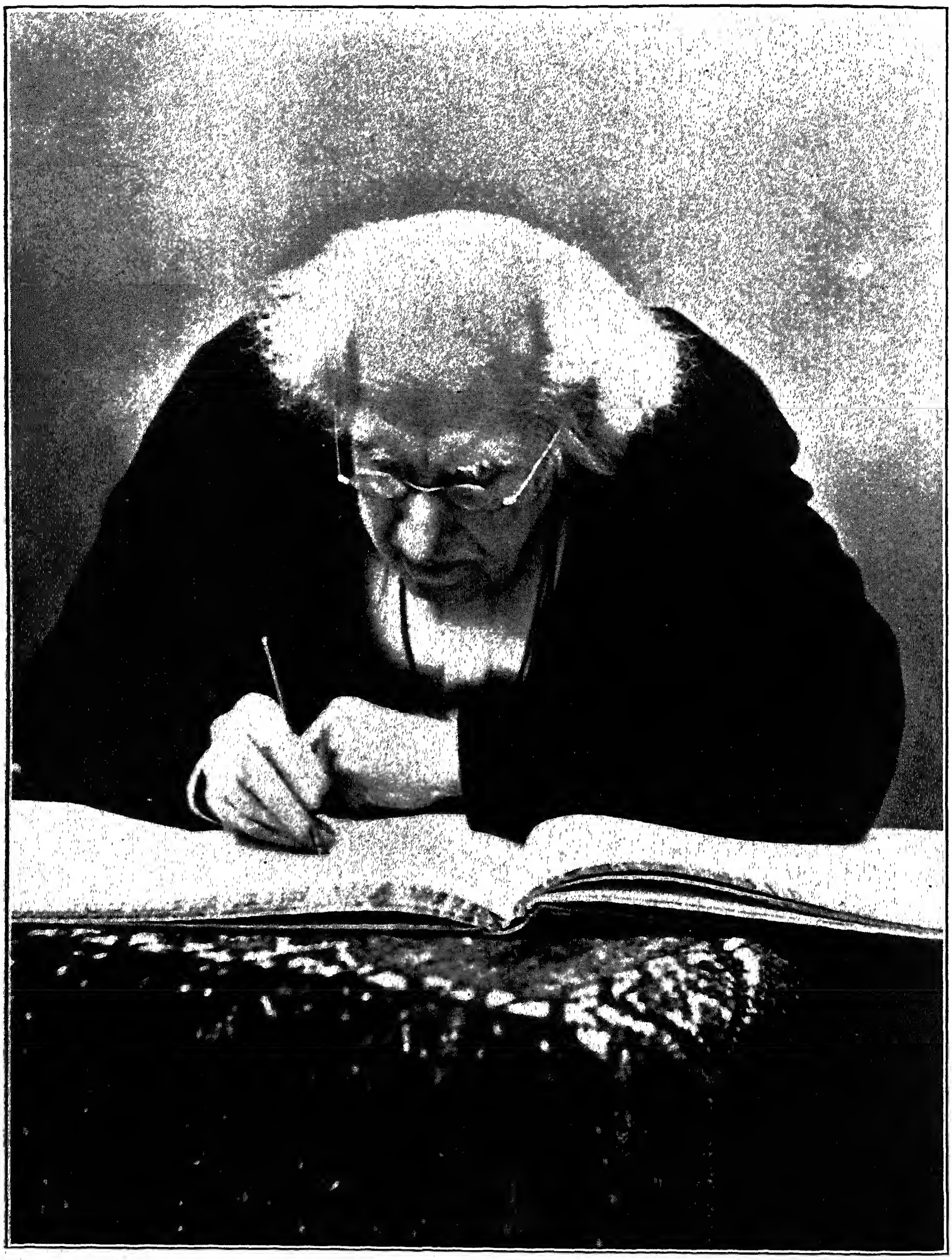
By Dr. JOSEPH JASTROW
EMERITUS PROFESSOR OF PSYCHOLOGY, UNIVERSITY OF WISCONSIN

There are here reproduced by the courtesy of *Life* the remarkable "candid camera" photographs taken in Paris in 1886 by Paul Nadar. They represent a remarkable man, Michel-Eugène Chevreul, distinguished chemist, physicist and, what is less well known, psychologist, an all-round man of science of the nineteenth century. His claim to interest is enhanced by the fact that he lived to the remarkable age of 103 years. Among the photographs is one showing the centenarian seated at a table with his son, aged 70, and a friend, discussing the philosophy of life, indicating an amazing activity of mind in old age.

There are several confrères of Chevreul still living in Paris, who remember him in his later years. As he was a boy of thirteen when Washington died, his life-span links the ages. There are in his career two episodes, separated by several decades, which proved his mettle as a psychologist—not a professional one—but by virtue of temperament and training possessing an insight into the treacherous ways of mind under prepossession. Chevreul was a spokesman for "natural causes" as opposed to the recourse to occult, mysterious and supernatural explanations. In his own words: "I hope to show in precise manner how *des gens d'esprit* under the influence of the love of the marvelous so natural to man, break through the limitations of the known and finite and have recourse to the *cachet de merveilleux et du surnaturel.*"

Before relating the incidents that brought Chevreul into the domain of psychology, it may be well to recall his contributions to chemistry. Dr. C. A. Browne, supervisor of chemical research, in the U. S. Department of Agriculture, kindly contributes the following sketch:

Michel-Eugène Chevreul (1786–1889) was born at Angers, France. His professional education began at Paris in the chemical laboratory of Vauquelin, whose assistant he afterwards became at the Museum of Natural History. In 1813 he was appointed professor of chemistry at the Lycée Charlemagne. It was during his association with Vauquelin that he began his important researches culminating in the publication in 1823 of the work on "Animal Fats." He demonstrated that animal fats are compounds of glycerin with various fatty acids, a number of which he isolated and characterized for the first time. His work in this field led to great improvements in the manufacture of soap and candles. In 1824 Chevreul was appointed director of the Dye Works of the Gobelins Tapestries, where he conducted researches on the chemistry of dyes and on color contrasts. In 1826 Chevreul was elected a member of the French Academy of Sciences, becoming also in the same year a foreign member of the Royal Society in London. In 1830 he succeeded his old master Vauquelin as professor of chemistry at the Museum of Natural History, of which he was also director from 1860 until his retirement in 1879 at the age of 93. For his important work upon stearic candles, Chevreul was awarded a prize of 12,000 francs in 1852. In his investigation of the substances formed upon boiling meat, Chevreul discovered the new organic compound creatine; he contributed also to the chem-



MICHEL-EUGENE CHEVREUL

AT THE AGE OF ONE HUNDRED, SIGNING THE REGISTER IN PAUL NADAR'S STUDIO.

istry of vegetable coloring matters. He issued a volume of memoranda on the history of chemistry, including alchemy. No other chemist has witnessed in the course of his life so long and so great a development of his science.

Chevreul came from a distinguished family, which for generations had taken an active part in the scientific and social life of their day; his father was an eminent physician. Through his association with the Gobelins industry, which he served to revive, he investigated the physics and psychology of color. For a score of years he lectured to artisans on the use of color. He formulated the laws of color contrast, distinguishing between simultaneous and successive contrast. For he realized that the positive and negative after-images were responsible for the subjective effects. The change of color-value upon different backgrounds —again introducing complementary contrast—and the differences in the "laws" of pigment and of color mixture were applied to the color schemes of textile and other designs.

There are some details of the life of Chevreul collected by his granddaughter, Madame de Champ, in 1930. She has preserved the contemporary accounts and interviews of the great celebration of Chevreul's one hundredth birthday on August 30, 1886. It was a festive occasion for the entire city of Paris, with receptions at the Hôtel de Ville, the Academy of Sciences, the museums, special gala performances at the Opera and the Odeon and a torchlight procession through the streets. He was accorded many honorary degrees by great universities, including Harvard. At his death in 1889, he was given a public funeral.

Reporters were active in obtaining Chevreul's reminiscences: of his visit to the Crystal Palace at London in 1851 (only a few months ago destroyed by fire), where he was received with honors; of his life during the siege of Paris, 1870–1871, where he presided at meetings of the academy, though he was then 85 years old, and expressed his consternation that a war of invasion and defeat should obstruct the progress of science. He recalled his official examination for a medical degree of a young man who impressed him with his great promise and whose name was Louis Pasteur. But mostly the interviewers of the distinguished centenarian were interested in the personal habits responsible for his amazing activity and longevity. Questioned as to his use of stimulants, "No," he said, "I was never able to take even a glass of wine, without its upsetting my digestion." He recognized its benefits to others, as he added: "I was president of the Société de Vins d'Anjou—only the honorary president, however." Beer was equally distasteful to him; nor could he endure tobacco smoke, explaining that his son was an inveterate smoker, but careful to keep the odor of smoke away from his father. So he drew no morals, assumed no poses; he just rejoiced in his fortunate heredity and habits.

The distinction here to be accorded Chevreul in commemorating the one hundred-and-fiftieth anniversary of his birth is the recognition of his services as a psychologist; for his flair in that direction, though touching the discipline at only a few points, was keen. Because of his psychological interest, he has recorded a chapter in the history of science that otherwise would have been forgotten. It appears in a memorable volume entitled "De la Baguette Divinatoire, du Pendule, dit Explorateur et des Tables Tournantes," 1854. The occasion thereof was the vogue of table lifting and of spiritualistic seances of the fifties, imported from the United States, for in reversal of the movement of empire westward, the empire of cults moved (or returned) eastward. The immediate occasion was the appointment of a committee of inquiry by the Academy of Sciences to inform the public as to the scientific interpretation of table-turning.

"Les sentiments moraux de l'honnête homme excepté, je suis prêt à abandonner tout ce que je fais, si on me démontre par expérience que je me suis trompé!"—Except for the moral feelings of an honest man, I am ready to give up everything I am doing if it is proved to me by experience that I am wrong. Chevreul's son is seated at the right; the photographer's father, Félix Gaspard Nadar, is standing. The latter appears seated in the following photographs. The secretary who recorded the conversations is shown standing in the last picture.

Chevreul was made the chairman and wrote the report. He made of it an extensive historical inquiry into the ancient and modern employment of the principle which he called that of the "exploring pendulum," and which we speak of as that of *subconscious and involuntary movement.*

The interpretation of the dipping of the "divining rod" in locating water, (and later, oil), as an involuntary movement of the forked stick in the hands of the dowser, was current long before Chevreul. Since Chevreul, that interesting chapter in the story of involuntary movements has been fully recorded by Sir William Barret in the *Proceedings of the Society for Psychical Research.* But if we go back a century or more, we come upon a very different attitude toward the mysteries of the divining rod. We then find a philosopher, Malebranche, discussing with a Father LeBrun (1689) the origin of the force that directed the witch-hazel fork to underground fortunes. Père LeBrun argued that since it was not the work of either God or the angels, the force must emanate from the devil. The same device was used to detect crime; and a learned physician of the same day contributed the remarkable hypothesis that "the corpuscles exhaled in the transpiration of the body of a murderer differ in the pattern of their arrangement from what they would have been had he not perpetrated the crime." Malebranche argued for a more rational explanation. Chevreul thought it well to present the background of outgrown beliefs, to make clear the gradual triumph of science over the occult.

The phenomenon that gives the second title in Chevreul's memoir is both more ancient and more modern; for it goes back to Roman days and has been revived even in our own day. It reached its peak when Chevreul was a young man, and to the generations since has been a forgotten episode. In 1808 appeared a book with the title "Le Pendule Explorateur," by Professor Gerboin of Strasbourg, one of a group of physicists who recorded hundreds of experiments demonstrating a new force. They felt confident that they were inaugurating a new chapter in physics. It fell to Chevreul—though not to him alone—to make plain that they were contributing to learned error, through ignorance of what since then has become a familiar psychological principle.

The apparatus or "pendulum" employed was very simple—substantially nothing more than a weighted ball suspended at the end of a string. The observations noted that the pendulum swung one way for one kind of substance or influence, and in an opposite way for another. It was claimed that when the string, with a bit of iron, sulfur, gold or other metal suspended from it, was held over the north pole of a magnet, the movement was from left to right, and over the south pole from right to left; held over copper or silver, it went right to left; over zinc or water, left to right; if held in the left hand, the movement was reversed; if held over an apple with the stem upward, it moved one way, if over an apple with the blossom-end upward, in the opposite way; if held over the head of a human subject, it rotated "positively," if over his feet, "negatively."

Pursuing their theories, they held that the force responsible for the movement was either "expansive" or "compressive," actively or passively perturbed, according to the form of movement of the pendulum. They found oxygen to be expansive and hydrogen compressive; the tips of the fingers were expansive, the middle joints compressive; some minerals were found to be expansive, and the diamond was neutral. This entire alleged new chapter in science is wholly mythical, the result of expectant suggestion. *The ball swings as you think it will or should.* It swings so readily

"Je ne vous ai pas tout dit! Mais dire n'est rien, il faut prouver, faire voir. Je vous ferai voir, il faut que vous voyez, parce que c'est quand je vois que je crois."—I haven't told you everything. But to talk is nothing. One must prove, must make sense. I will make you see. You must see because with me seeing is believing.

"JE N'AIME PAS M'OCCUPER DE PLUSIEURS CHOSES À LA FOIS!"—I DON'T LIKE TO BE BUSY WITH A LOT OF THINGS AT ONCE.

that the holder is wholly unaware that he is giving the impetus. The theory is all a rationalization upon a mistaken premise.

And that was Chevreul's principle of explanation. He proved it by experimenting upon himself; for at first he too found that the pendulum worked, as predicted, when held over a dish of mercury. He made his "exploring pendulum" by attaching an iron ring to a thread of flax. To test whether a physical force operated the pendulum, he interposed a glass plate between the iron ring and the mercury. Again, to his surprise, the oscillations diminished and then stopped entirely, and started again when the glass plate was removed. Suspecting that the movement was due to the difficulty in holding the pendulum steady with a free arm, he rested his arm on a support; the oscillations diminished but did not cease. Still suspicious, he had his eyes blindfolded and let some one else interpose the glass plate without his knowing when; and *nothing happened,* though he held the pendulum still for fifteen minutes. This observation marks an important moment in the annals of suggestion.

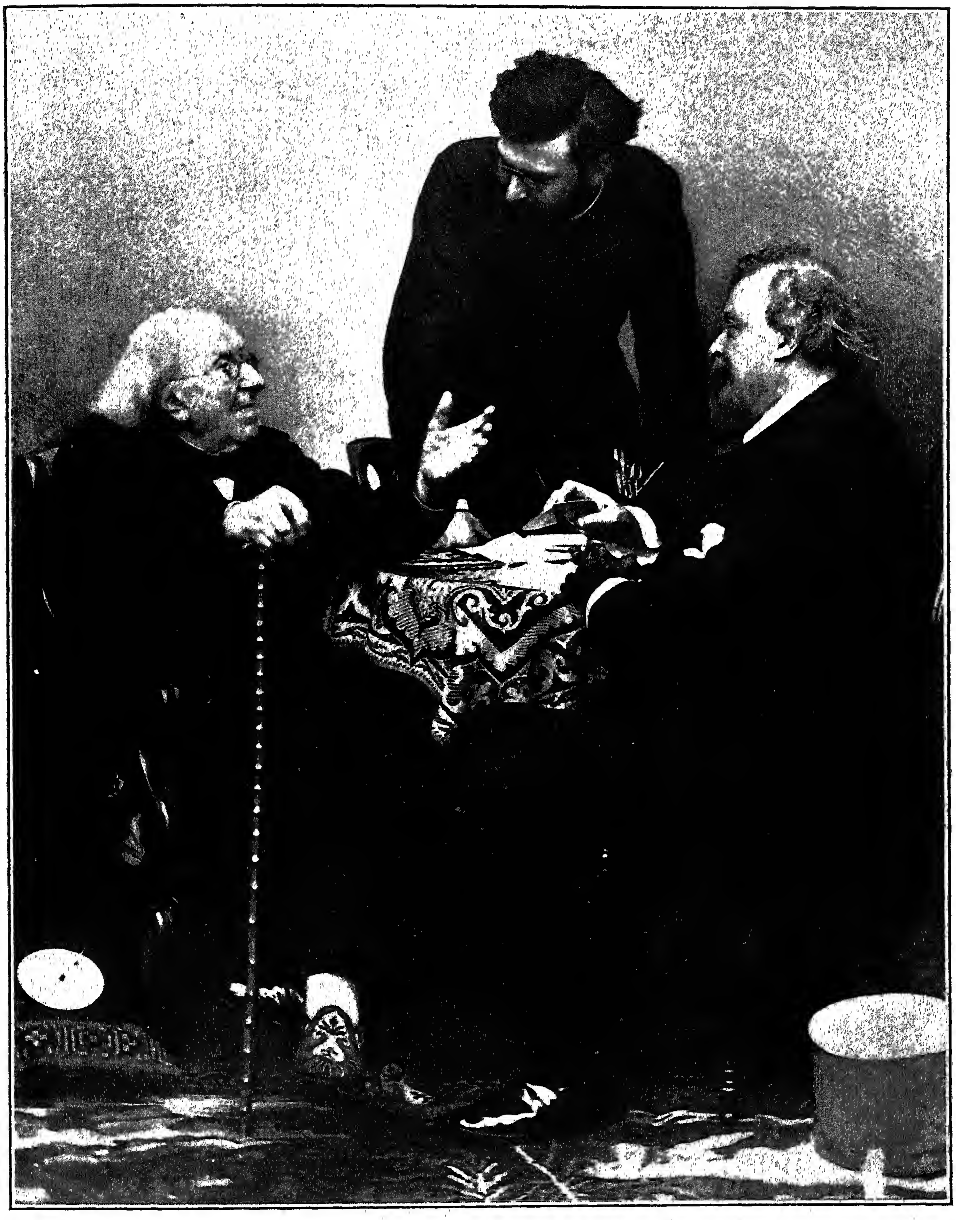
Chevreul had made a great discovery, which stood by him for life. "So long as I believed the movement possible, it took place; but after discovering the cause I could not reproduce it." He adds that the experiments "might be of some interest for psychology and even for the history of science." They show how easy it is "to mistake illusions for realities, whenever we are confronted by phenomena in which the human sense-organs are involved under conditions imperfectly analyzed."

When accordingly in 1853 Paris went wild over turning and talking tables, Chevreul had only to bring forward his notable letter to his friend Ampère, published in the *Revue des Deux Mondes* in 1833, concerning a "particular class of muscular movements," which established convincingly the principle of involuntary movement. But these experiments were actually performed in 1812, when Chevreul was twenty-six years old, and as a direct challenge to the Gerboin group of physicists. So the span of Chevreul's interest in this psychological problem covers the period from 1812 to 1854.

He thus brought together under one principle three phenomena which popular belief and practice presented to science; dowsing, a "vulgar error" supported by some "scientific" investigation; the "exploring pendulum," contributed by prepossessions of a group of physicists;[1] and table-moving, a spiritualistic phenomenon. The divining-rod is an ancient practice, retaining adherents to-day; there was held a congress of "diviners" in 1932. The ball and string, as a fortune-telling device, goes back to Roman days, when it was held inside a tall glass. As the letters of the alphabet were spoken, the ball would swing to the side of the glass and ring out the correct letter. There are also accounts of holding the "pendulum" above a written alphabet and thus spelling messages, anticipating the Ouija board, which had its great vogue in the closing decades of the nineteenth century, but its predecessor in the fifties in the Spiritualistic movement.

The ball and string device was forgotten and resurrected several times, its latest appearance in our own century as a "sex-detector." The claim went forth

[1] Somewhat earlier (1845) than the table-turning episode, appeared the claims of Baron Reichenbach, a distinguished chemist, to the discovery of another new force which he named "Od," which likewise was found to have positive and negative qualities and to behave differently for different metals, etc. Here the error resulted from trusting the reports of "sensitives," mostly hysterical subjects following through suggestion the leads of Reichenbach's prepossessions. There is no record of Chevreul's interest in the episode of "Od." The details of these "aberrant beliefs" will be found in my "Wish and Wisdom," 1935.



"ARAGO AVAIT DANS SON RAPPORT SUR L'HELIOGRAPHIE OMIS DE MENTIONNER LE NOM DE NIÈPCE, LE VÉRITABLE INVENTEUR."—IN HIS STORY ON HELIOGRAPHY, ARAGO HAS OMITTED TO MENTION THE NAME OF THE TRUE INVENTOR, NIÈPCE.

that in the hands of a man or when held over anything masculine, the ball would swing to and fro; and when held by a woman or over a feminine article, it would swing in a circle. It all occurs in accord with the principle that Chevreul enunciated.

The public agitation aroused by turning and communicating tables was far more wide-spread than that of any similar movement; it touched upon the vital issue of survival and the personal emotions of contact with the departed. The wave of spiritualistic seances rose even higher in England than in France, and there brought forward another distinguished champion of rational belief in the person of Michael Faraday. So two great leaders accepted the social obligation of science to correct false views and allay agitation. Faraday came to the same conclusion as Chevreul, that the table moved through the involuntary movements of the "sitters" and expressed their knowledge and wishes. Faraday reduced the matter to a test by a simple device consisting of two small boards with glass rollers between them, which was sensitive enough to indicate the slight involuntary movements of the hands of the "table turners."

Faraday mentions that he called on Chevreul at his laboratory in 1812 and again in 1845, but their interests were diverse. Chevreul had before him Faraday's report in the London *Times* (June 30 to July 2, 1853). Both distinguished scientists regarded it as an interruption to their scientific labors to devote time to correcting popular opinion; but the occupation was far more congenial to Chevreul than to Faraday. In his book, Chevreul gives an account of the origin of Spiritualism in New York State, and comments on the fact that mediums or their controls are "not always moral or polite or in good taste in their language," and depart from truth in their predictions. Faraday was roundly denounced as a "materialist" by "spiritualists" generally, and by believers in "psychic" powers, including Mrs. Browning. As Robert Browning wrote the satirical "Sludge the Medium," the two poets seemed to have been of different minds.

Faraday was sorely troubled by the credulous condition of the public mind. The sharp contrast of the two temperaments appears in a letter by Faraday complaining of the necessity of "turning the table on the table-turners." He writes: "Consider my age (61) and my weariness, and the rapid way in which I am becoming more and more inert." Faraday died in 1867; his memory had failed him completely. That an instance of remarkably early senescence and one of its extraordinary absence should have occurred in two distinguished men brought together by a common interest, gives an added touch of interest to this episode in one of the bypaths of psychology. Thus did a great chemist and a great physicist serve the cause of science by recognizing a psychological principle.

All these matters are familiar to-day, but were far from generally recognized in those seemingly distant days when the generations contemporary with Chevreul —for he overlapped several—were demonstrating the practical benefits conferred by science and the principles of right thinking which they fostered. In the line of this rationalistic tradition Michel-Eugène Chevreul deserves a distinguished place.

COLLECTING FOSSIL ALGAE OF THE CANADIAN ROCKIES

By Dr. CARROLL LANE FENTON and MILDRED ADAMS FENTON

WEST LIBERTY, IOWA

LIKE all ranges of the Rocky Mountains, those in Banff and Yoho National Parks are young. Scarcely 70,000,000 years have passed since they appeared as low chains of hills above forests in which armored dinosaurs roamed. Many of their peaks took form within the last thousand centuries, receiving their final steepening touches less than 10,000 years ago. If these figures still seem great, recall that the present Appalachians have passed the 200,000,000 year mark and still are by no means the world's oldest mountains.

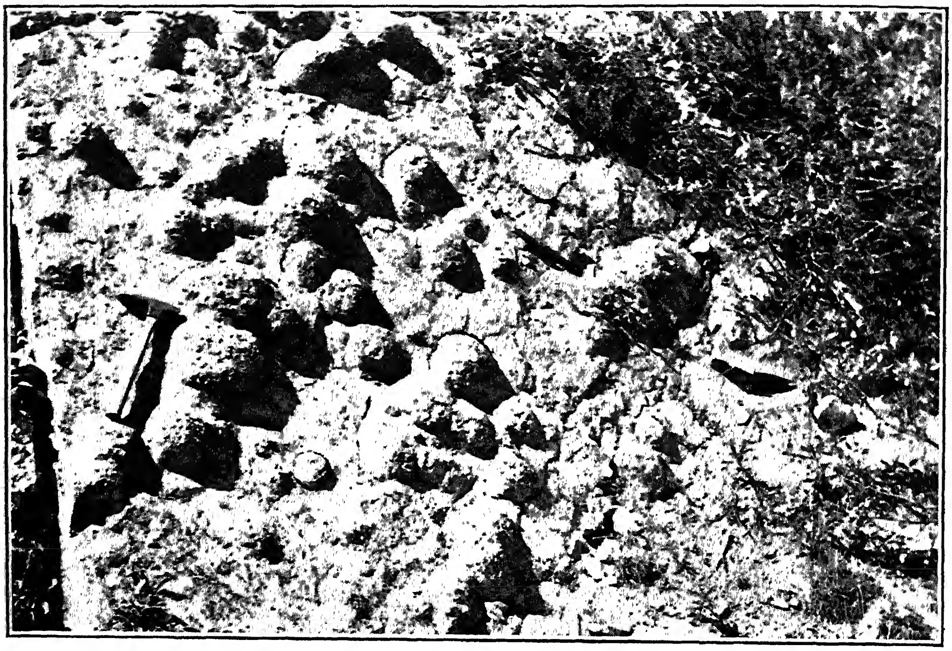
Despite their youth as highlands, the Canadian Rockies contain strata that are very old. Deposited in Proterozoic times, the age of the most ancient may be estimated at 650,000,000 years. Great thicknesses date from the early Paleozoic era, 400,000,000 to 540,000,000 years ago. Comparatively few were formed in the Mesozoic or "Age of Reptiles" and so are less than 200,000,000 years old. Most of these rise in rounded foothills or lie in valleys near Banff, forming no significant part of the mountains even along their front.

The older rocks were formed during times when what now is western Canada lay beneath shallow seas. Those seas stretched southward from the Arctic Ocean, linking waters with others that advanced across central North America or crept northward from bays in Arizona. Into those seas many rivers drained, bringing loads of sand, silt and dissolved minerals that sank and hardened into beds of stone. Through age after age those sediments settled, till they formed vast thicknesses of rock in the sinking marine basin.

Deposition was interrupted, of course. At some times little waste came from land; at others there was a great deal. During several epochs the sea floor arose till the hardened muds and sands were exposed, to be worn by winds, rains and streams. But time after time they sank again and were covered by new sediments. Not till the Mesozoic Era ended did uplift achieve dominance as tremendous forces, pushing from the westward, bent and raised the hardened rocks. Before that shove the strata formed folds, slid over one another or broke into great, tilted blocks. When the earthquakes of uplift ceased, those blocks formed ranges of mountains rising high above the plains.

Those mountains were what took us to Banff in search of primitive fossil plants. Rocks containing them lay beneath the plains; but where mountain building had not exposed them, they were deeply covered by later strata. In the Rockies, ancient marine beds stood forth in cliffs, ridges and the walls of canyons. What if they were tipped awry, bent or crossed by those breaks known in geology as faults? They were out where they might be seen and reached—and good roads or trails, built for tourists, led to many of them.

While other visitors danced, golfed or admired the Banff view, we were busy with topographic maps. We sought advice from alpinists and guides, examined specimens in the park museum, and discussed routes with a warden who amazed



ALGAE AS THEY GREW

THESE COLONIES BELONG TO A NEW GENUS AND SPECIES. THEY LIE UPON HARDENED SEA MUDS WHICH A GLACIER PLUCKED FROM A PEAK AND DROPPED IN THE WIDE CORAL VALLEY.

us by knowing what fossil algae were. He also urged us to keep watch for living things. "There will be mountain sheep in that canyon and goats on most of those ridges. On the Pass, keep an eye out for grizzlies; they will do no harm but are worth seeing, and it's great to watch one dig for squirrels. If you camp, watch out for wolverenes: some of 'em live near Fossil Mountain. There's naught can wreck a grub cache so bad as a hungry wolverene!"

Our first finds were made near the highway, barely six miles from Banff. Passing beaver ponds with their unkempt houses, we came to a salt lick prepared so that bus passengers might see mountain sheep. Four rams mounted a slope as we approached and watched while we struck out through the woods. The indistinct trail merged with a creek bed which became a channel filled with rocks dropped by a vanished glacier. Several showed deep scratches made when the ice forced them against other sharp stones.

Where the channel became a box canyon we found beds filled with fossil plants. Each fossil was a biscuit-shaped mass of limestone one to four feet in height, probably built by several species of jellylike red algae living in close association. As they grew these algae deposited layers of the mineral calcite within their jelly. When growth was rapid the layers were thick; when it was slow, they were thin; when it almost stopped, breaks or partings were left between layers. Very probably, a layer and a break represent a year, for plant growth in ancient northern seas must have been helped by the long days of summer and retarded by winter, when days were short and the sun stood low. We looked for

THE "GIANT'S PAVEMENT"
BEDS OF THE LARGE ALGAE CALLED *Collenia (?) prolifica* BY WALCOTT. THEY LIE BARELY THREE MILES FROM THE FAMOUS SKOKI CLIMBING AND SKI CAMP.

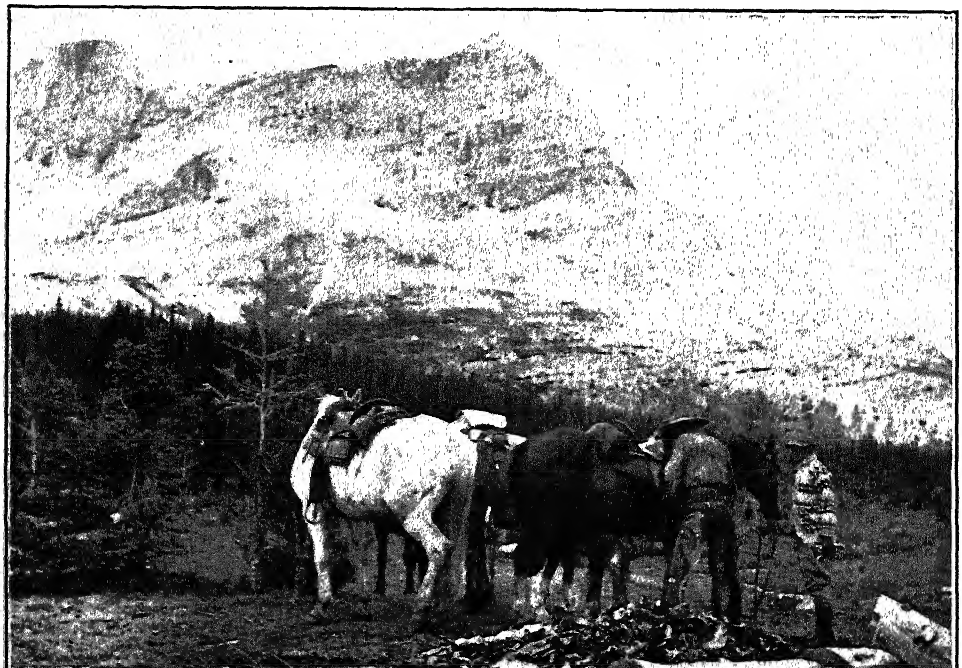
definite seasonal layers in limestones containing the fossils, but failed to find them. The most we could discover was rocks in which complex carbon-stained bands seem to indicate periods of several years in which plant life was abundant, separated by intervals in which it was scarce.

The Banff fossils looked much like some discovered years before by the late Dr. Charles D. Walcott, who spent many summers collecting in the Rockies. We might have gone direct to Walcott's locality by trail, past mountains amazingly tilted, bent and broken by uplift. It was simpler, however, to start from Lake Louise. Even there, it seemed that we should need a guide, pack string and camp outfit—all the troublesome essentials of collecting among mountains far from lodges or camps.

A chat with a warden showed us to be wrong. "Need a pack outfit to reach Tilted Mountain? No! Didn't any one in Banff tell you that Jim Boyce keeps his ski camp open all summer? Go up when and as you please, with no worry about packs. Stay in one of Jim's cabins: the beds are good and so is the grub. Collect as many days as you like, use horses if you wish, and let Jim pack your fossils out. He'll leave 'em for you here at my cabin. And if I can do anything for you, just send word down by a guide."

Thus we found ourselves "camped" in a log lodge where dinner was served in courses and strawberries (packed thirteen miles on a cayuse) greeted us at breakfast. We also were able to answer critics who maintain that geology blinds one to other phases of nature and mars every fine scene. For four days we climbed and collected among alpine ranges where gray, buff and brick-red rocks were tilted into beautiful patterns.

THE RECORD OF ANCIENT FLOOD OR STORM
PEBBLES AND MUD WERE MIXED TOGETHER IN THIS BRECCIA, PERHAPS 650,000,000 YEARS OLD.

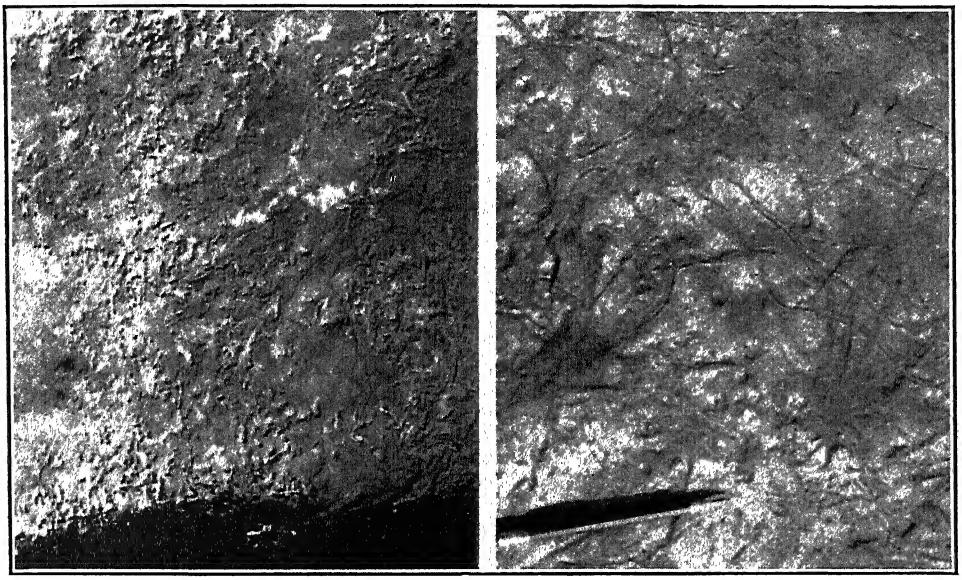


SADDLING AND PACKING
A GUIDE HAS COME FOR THE COLLECTORS AT THE END OF A DAY'S WORK NEAR PTARMIGAN AND PIKA PEAKS, A DOZEN MILES FROM LAKE LOUISE.

They lost none of their design because they appeared as limestones, dolomites and quartzites thrown into blocks by faulting. Peaks were not ships or castles, it is true, but they gained meaning as the results of structure, weathering and erosion. A folded and faulted ridge lost whatever poetry it may have possessed as the "giant's washboard," but it received its due of glamor from a tale of hardening, compression, uplift and fracture running through 300,000,000 years.

"Other phases of nature" would not be ignored. Structure of fault blocks explained groves of larches, varied strata accounted for waterfalls, and the melting of a small glacier provided hoary marmots with homes. Ptarmigan chuckled while we examined a conglomerate and a mountain goat stopped to watch as we measured beds of micaceous shale. A mule deer met us on the "giant's pavement" that proved to be dolomite filled with masses of algae.

Those algae, discovered and named by Walcott, did not grow in domes or reefs. Instead, they covered the sea floor in banks, their colonies crowded so closely that they grew in odd, distorted columns. Little mud was able to settle between them, but there was even less in the water covering the massive plants. Many of the colonies surround cavities that still are but partly filled with sediment, though they must have remained open for years before algal growth covered them.



TRACES OF ANCIENT LIFE

Left: "NULLIPORE" ALGAE—PART OF A SLAB IN WHICH SMALL, BRANCHING FOSSILS LIE IN A MATRIX OF HARDENED LIME MUD. *Right:* FOSSIL SNAIL TRAILS—TRAILS MADE BY SNAILS THAT CRAWLED AND FED ON CAMBRIAN SANDS 540,000,000 YEARS AGO.

Though clear and free from coarse mud, water on the algal banks was shallow. Where plants did not protect the bottom, small waves were able to reach it and pile up ripple marks. In other places currents dug channels only a few inches wide. In many spots and times, storms broke up the half-hardened sea

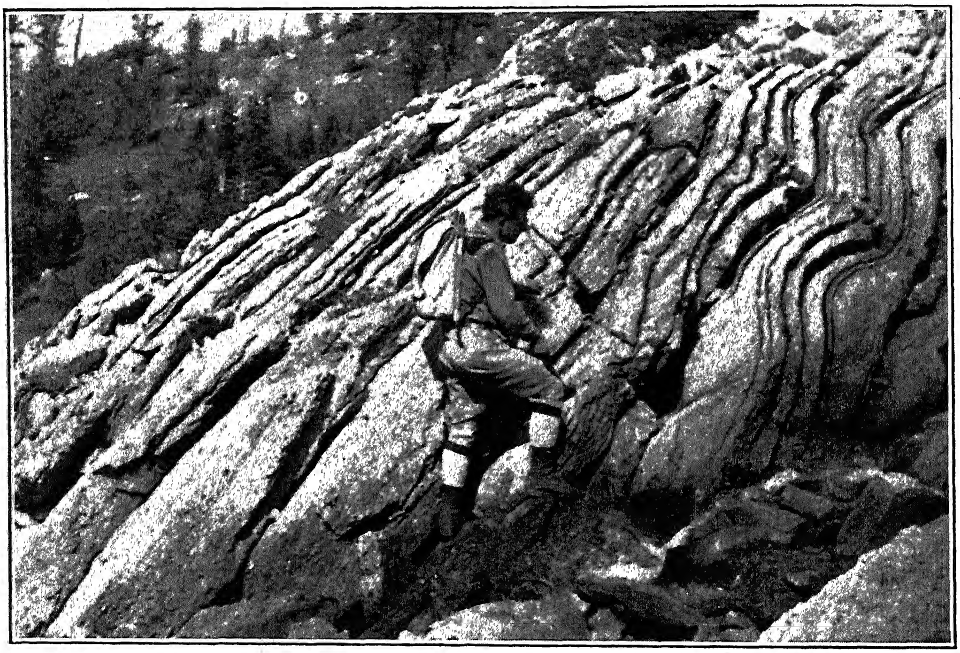
floor and turned it into mud and pebbles. For a while these were tossed and rolled about; then the waters quieted and they sank to form beds of mud and flat pebbles. Some of these fill spaces between algae, while a few, in very ancient rocks, contain rolled bits and pebbles of algae broken and worn by storms.

Such rocks, called edgewise breccias or conglomerates, are common among formations containing algae, as well as in many others. With or near them are mud cracks, ripple marks, current channels, rain prints and other traces that mark shoals or mud flats. Even when doubtful cases are omitted, they seem to prove that many ancient seas were shallower than the majority of modern lakes. Over hundreds, even thousands, of square miles they were less than thirty feet deep. Some contained so little water that each dry season laid their floors bare as steaming sand or mud flats.

The Canadian sea was not so shallow, but it plainly was not very deep. Many strata gave evidence of shoals, while others formed in later seas showed kindred structures. Not one bed suggested deposition in water of great depth.

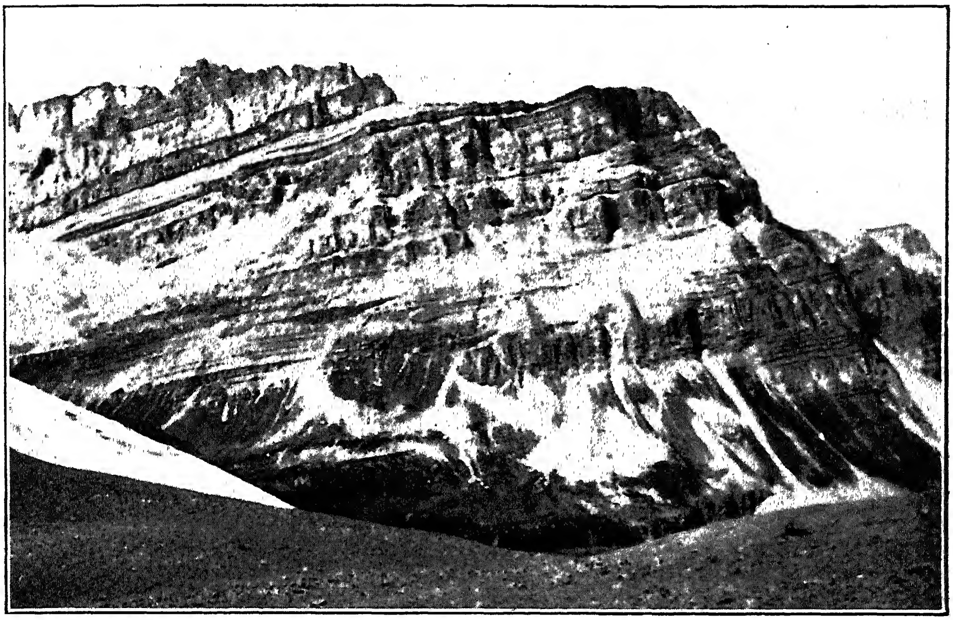
Like many shallow-sea deposits, these were rich in fossils. In one limestone we came upon true reefs, though they did not reach three feet in thickness. A slope provided many corals, broken by glaciers from strata exposed on the high slopes of Fossil Mountain. Blocks of gray limestone near a pass were filled by round balls called pisolites. They gave promise, at least, of being algal; so we took all the specimens we could carry in comfort. Why shouldn't we when the cabin and our *cache* were barely a mile away?

We planned to walk that mile in haste;



FOLDS OR FOSSILS?

LAYERS SO COARSE AND SO THOROUGHLY CRYSTALLIZED THAT THEIR NATURE CAN NOT BE DEFINITELY DETERMINED.



UPLIFTED MARINE BEDS

THESE CLIFFS OF LIMESTONE AND DOLOMITE BEGAN EXISTENCE AS LAYERS OF MUD IN A SEA THAT STRETCHED SOUTHWARD FROM THE ARCTIC OCEAN.

A BANK OF LARGE ALGAE

HERE HUGE COLONIES OF LIMY RED ALGAE GREW SO CLOSELY TOGETHER THAT THEY FORMED BEDS OF ROCK, EVEN WHILE THEY STILL WERE ALIVE.

instead, we stopped long beside a slab lying near a small creek. It had been plucked, carried and dropped by a glacier melting as it moved toward the Bow Valley. Throughout these adventures, it preserved two dozen biscuit-shaped masses of algae belonging to a new genus and species. They dotted the upper surface of the rock, lying as they once grew on the muds of a Cambrian sea floor. Again camera, notebook and tape were used; then a chisel pried off specimens that filled both knapsack and arms. That last mile to the cabin was not made quickly, and many sighs of relief were heard as those algae joined the lot waiting for pack-horse and packer.

After Lake Louise came Yoho Park, whose fossils have made it famous even where its scenery is unknown. Dr. Walcott found excellent animal remains at Ross Lake, but made no mention of algae. We were lucky enough to find three types: one the shape and size of pigeon eggs, another so massive it almost made reefs, and a third that consisted of countless branches tangled into dolomite slabs. They suggested the modern "nullipore" algae, whose remains become indistinct a short time after they die. Other "nullipores" form rocks in the Big Horn and Teton ranges of Wyoming, where they look like mere coarse-grained versions of the strata in cliffs above Ross Lake.

Mountains a few miles away provided other egg-shaped algae, buried in sediment that was a mixture of dolomite and sharp-edged sand grains. The dolomite was precipitated from clear water; the sand may have been blown out to sea from arid lands bordering the Cambrian shoals.

A PAUSE ON A PASS

THE FOSSIL HUNTER IN CANADA'S ROCKIES FINDS HIMSELF IN PLACES OF SCENIC BEAUTY AND BIOLOGIC INTEREST. HERE IS HIGH ALPINE COUNTRY—AT AN ELEVATION OF BARELY 8,200 FEET.

WALCOTT'S BURGESS SHALE QUARRY

AUTHORS ARE COLLECTING FOSSILS OF PLUME-LIKE ALGAE FROM SLABS DISCARDED BY EARLIER WORKERS.

Sandstones of greater age contained no algae, but they did bear the filled trails and burrows of bottom-dwelling animals. Some trails were made by snails as they crawled and fed on the soft bottom. We could trace ridges pushed up and pressed by shells, furrows dug by wide, soft feet, and cross wrinkles built as the muscles in those feet contracted. Mud and mica grains in the sands made them so plastic that the trails were preserved long after the snails vanished.

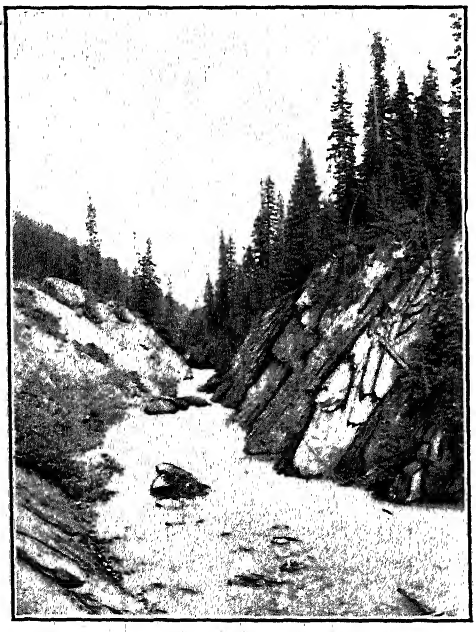
Many burrows probably were the work of annelids, but a few, marked by crisscross lines, plainly were the work of trilobites—ancient and remote cousins of the king crab. Whether they dug for food or to lay eggs is not certain; perhaps shallow burrows are food holes and deep ones are nests sunk into specially plastic sand. Trilobite "tests," like the shells of snails, were lacking. Both were dissolved by carbon dioxide in the dark, muddy sand.

Our next objective was the Burgess Shale quarry, where, in strata a half billion years old, amazing fossils have been found. The shale was discovered by Dr. Walcott in 1909 when he stopped to push a stone from the trail. Striking it with his pick (nicknamed Jonah), he split off a few black slabs. On them were remains of infant trilobites and round lamp-shells or brachiopods, preserved in shining films of carbon. Search located the ledge whence the loose block had come, on a ridge between Mounts Field and Wapta. Camp was pitched among firs far below, a quarry was opened, and thousands of fossils were taken out. For many summers Dr. Walcott and his aides returned, their collections now being among the chief treasures of the U. S. National Museum.

With binoculars we saw the quarry

from the chalet beside Emerald Lake. The trail to it was very steep, so we chose a longer but easier one climbing from the Yoho Valley. On the way, we paused to pick whortleberries, to watch a moose and to photograph ptarmigan chicks. Rocks lay near the trail on Yoho Pass, their bluish strata formed by branching coralline algae buried in dolomite. Specimens were selected and cached near a fir tree, to be picked up on the return trail.

At the quarry we set to work on slabs thrown aside by Walcott's collectors. The frosts of a dozen years had split them, revealing shells, trilobites and even glass sponges. More interesting to us were silky, carbonized filaments of green seaweeds that covered some surfaces. With them were fronds that seemed to be relatives of the laminarian seaweeds now



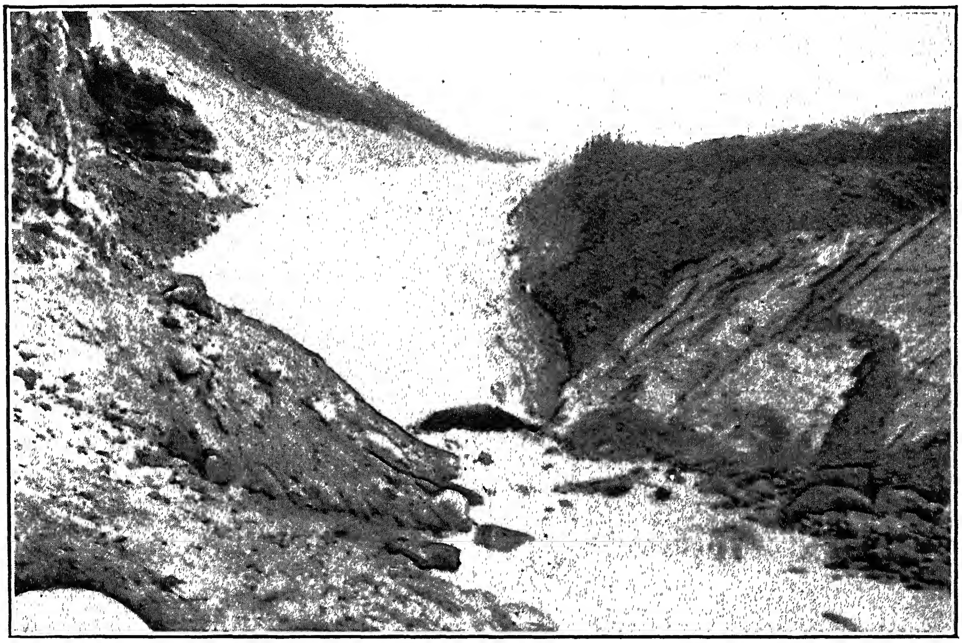
UPTURNED STRATA
ROCKS ALONG THE KICKING HORSE RIVER SHOW HOW INTENSELY ANCIENT SEA BOTTOMS WERE BROKEN AND TILTED WHILE THE ROCKY MOUNTAINS WERE RISING.

found on many shores. Though there was no hint of shore lines on Mounts Field or Wapta, the strata did agree with others in giving evidence of shallows not far from the one-time Burgess Pool.

A trail through the Yoho Valley itself led to still other ledges of the supposed coralline algae. Then it passed two lakes, crossed a glacial creek, and in steep switchbacks climbed a ridge descriptively called the Whaleback. On its shoulder we paused to admire a maze of deep valleys, horn peaks and glaciers clinging to the faces of cliffs. Then we turned to algae as big as those in the canyon near Banff and from them to biscuit-shaped forms that would make still another new species. They may have lived in deeper water than the others, for beds among them showed ripple marks so large that we could pick them out on mountain sides more than a half mile away.

Work in the Yoho showed what an array of data are needed if fossils are to reconstruct life during remote ages. Good specimens are far from enough; they must be accompanied by descriptions and measurements of beds, rock samples for sectioning, plus photographs and annotated sketches dealing with sedimentary structures. A single fossil often required a half-dozen rock samples, three or four negatives and as many pages of notes. With so much to do, progress was slow. We called two miles per hour excellent speed on all but thickly wooded routes where few rocks could be found.

Our trips also showed how readily geology may be enjoyed by travelers equipped and willing to see it. Our companions on one day were physicists: they discovered some excellent fossils and wrestled with problems involving concretions. A school girl was with us at Yoho Glacier, where she learned what crevices and seracs meant. Two bell-



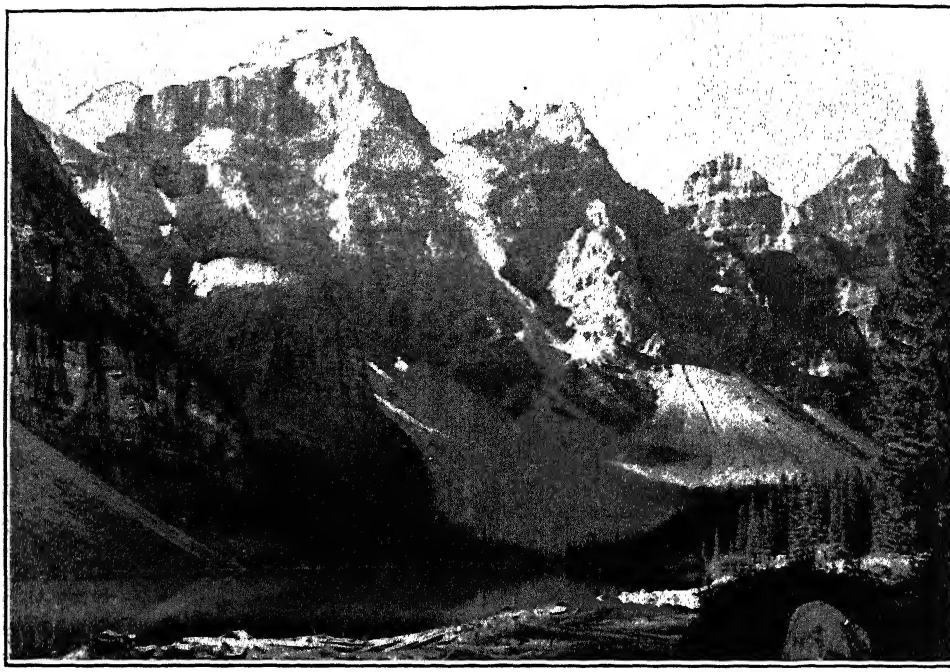
YOHO GLACIER
ONE OF THE MANY GLACIERS THAT STILL CARRY BLOCKS OF FOSSIL-BEARING LIMESTONE TO PLACES WHERE COLLECTORS CAN REACH THEM.

hops on leave visited strata so complexly folded and broken by faults that their proper sequence still is uncertain, and an attorney gained new respect for moraines while we looked for slabs of coralline algae small enough to go into knapsacks. He also marveled at our willingness to put stones in those packs, though miles of trail stretched before us. When geology meant such loads as those, how could we come to the mountains for pleasure?

Mid-August found us in the Valley of Ten Peaks, a few miles south of Lake Louise. In the party were our two physicist friends. Having walked through much of Yoho and Banff parks, they were ready to see more of fossils.

We took the trail one chill morning as clouds whirled about Wenkchemna Peak. For a thousand feet we climbed by switchbacks; then the trail entered a wide valley where larches already were turning yellow. It led to the bowl where a glacier once rose—a basin the geologist terms a cirque, but that prospectors know as a "half-kettle" valley. At the bottom lay a blue tarn whose bed had been dug in hard sandstone as ice ground and shoved its way down the valley.

Fossils were present, though not common. Sandstone ledges held tubes probably built by the worm-like creatures called phoronids. Other ledges contained trilobite tracks, but no pits showing where they had dug for food. At Sentinel Pass we found blocks of the egg-shaped algae, though slopes were too steep to permit climbing to the brown strata from which they came. We contented ourselves with a few talus specimens and then used binoculars to distinguish the larger rock groups making up the precipitous mountains.



FOUR OF THE GLACIER-CARVED TEN PEAKS
THEY ALMOST SURROUND A VALLEY NEAR LAKE LOUISE. BEDS OF EGG-SHAPED ALGAE LIE IN THEIR HIGH CRAGS, BUT SPECIMENS MUST BE SOUGHT IN DRIFT AND TALUS.

By a camp fire that night we discussed our finds. Our friends had specimens that defied purely physical explanation, though it had been suggested for fossil algae far more plantlike than those. They also possessed negatives that recorded rare views of glaciers, peaks and red-walled canyons descending to milky glacial streams. For us there were sections, notes on rocks too large for collecting and small slabs showing that egg-shaped algae grew widely in one Cambrian sea. For all, there were memories that would last, glimpses of beauty to be considered and problems that would call for solution long after we should leave the mountains and return to our lowland, workaday homes.

THE ANNUAL EXHIBITION REPRESENTING RESEARCH ACTIVITIES OF CARNEGIE INSTITUTION

By THE EXHIBITION COMMITTEE
CARNEGIE INSTITUTION OF WASHINGTON

Active interest in the current progress and development of scientific knowledge and a clear desire to appreciate the significance of these advances, especially in respect to what may be termed their human aspects, has been increasingly demonstrated by the intelligent public during the past fifteen years. Scientific investigators and teachers who are the readers of the Scientific Monthly are being called upon with increasing frequency for expositions of their subjects which are suited to this general audience, and a description of the procedure which has been developed by the Carnegie Institution of Washington for the annual presentation to a non-technical audience of some of the latest developments in the program of the Institution may be useful to others in meeting a similar problem.

The Carnegie Institution, as is well known, is a research organization endowed by Andrew Carnegie, and its activities cover a wide field, with laboratories in various parts of the United States, with field investigations in every part of the world and with members of university staffs here and abroad as research associates. The Institution has three major departments in the physical sciences—Mt. Wilson Observatory, and the Geophysical Laboratory and the Department of Terrestrial Magnetism in Washington. The Division of Animal Biology includes the Department of Embryology in Baltimore, the Nutrition Laboratory in Boston and the Department of Genetics at Cold Spring Harbor, Long Island. The Division of Plant Biology has field stations and laboratories in many locations in the West. The Division of Historical Research spends a major part of its efforts in archeological studies of the Early American (Indian) culture.

This wide geographical distribution of activities is a factor of importance in assembling an exhibition of current research results. The trustees of the Institution hold their annual meeting at the Institution's Administration Building in Washington in December, and for many years it has been the custom of the president to arrange at that time a series of exhibits showing a selected group of recent developments in the Institution's researches. For three days after the trustees' meeting these exhibits are open to the general public. One of the primary factors which lends importance to these exhibits is the fact that the investigators who actually carried out the researches which are exhibited are also there in person to demonstrate or explain them and to give an opportunity to visitors for a close personal association with the work which can be achieved in no other way. The occasion of these exhibits has served as an opportunity to bring together each year some of the members of the research staff, and thus it has been possible to minimize the disadvantages inherent to the scattered geographical location of the departments.

The exhibits are organized by a committee which is appointed from year to year. This committee functions mainly as a coordinating agent. It helps in the

selection of problems to be exhibited; it handles routine arrangements in regard to the physical facilities; and it is responsible for supervision of the concise statements prepared by the investigators for the descriptive pamphlet which is issued every year. Exhibits are prepared by the members of the research staff whose problems are shown. The exhibits material is brought to Washington from the various laboratories and is assembled there.

On the last day of the exhibition the committee and the exhibitors hold a meeting at which, among other matters, suggestions as to the improvement of the exhibits are discussed. At these meetings the question is frequently raised as to whether the exhibits should be arranged and labeled so as to be self-explanatory or whether they should require a demonstrator. No general decision or agreement on this question has been reached. Since these exhibits represent individual research projects and are prepared by men who did the work and who in many instances are leaders in their respective fields, a certain degree of freedom in the choice of method of presentation is found to produce the best results. Each exhibit expresses the individuality of its author not only in respect to the problem but in respect to the presentation as well. This intimate relation between the exhibit and the men who did the research is the most valuable and unique feature of the Carnegie Institution exhibits. Not only are these exhibits prepared by the various investigators themselves, but, as mentioned above, these men are always on hand either to demonstrate their exhibits or to answer the questions of the visitors.

A series of seven or eight lectures, each twenty minutes in length, is arranged for the lecture hall during the three days. This gives each exhibitor an opportunity for a more connected and detailed presentation of his work to an audience which expresses its interest in his particular subject by attending at the time indicated. These concise and authoritative statements are very carefully prepared and later published, bringing to a wider public in a permanent form the essence of the temporary presentation of the work which the exhibit constitutes.

A short description will be given here of the eleven exhibits shown last December. This description follows closely the statements prepared by the exhibitors and published in a 56-page pamphlet distributed among the visitors.

The Present-Day Maya Indians of Yucatan

A broad historical project relating to the development of the Maya civilization comprises an important part of the Institution's program. Archeological investigations in Yucatan and Guatemala are supplemented by documentary, environmental, biological and sociological studies relating to the evolution of the Maya culture. This project constitutes the major part of the activity of the Division of Historical Research and is carried on in cooperation with several other departments of the Institution, as well as with a number of research associates located at several universities.

The exhibit on "The present-day Maya Indians of Yucatan," which was prepared by Dr. Morris Steggerda, of the Department of Genetics, showed the results of a study in which the Department of Genetics, the Division of Historical Research and the Nutrition Laboratory took part. It has been found that the Maya possess a uniquely high metabolic rate combined with a low pulse rate. This unusual condition may be innate, in which case it becomes a useful criterion of race; or it may be caused by environmental factors such as climate, clothing and food. A detailed study of the principal foods of the population in the village of Piste, Yucatan, reveals that corn (maize) forms 75 to 85 per cent. of the

FIG. 1. THE FOOD OF THE YUCATAN MAYA
SAMPLES AND MODELS OF VARIOUS FOODS, SAMPLES AND DESCRIPTIONS OF ACTUAL MEALS AND PHOTOGRAPHS ILLUSTRATING THE DAILY LIFE OF THE MAYA INDIANS OF TO-DAY.

diet of the Maya; meat forms 10 to 15 per cent. and vegetables 5 to 10 per cent. This high carbohydrate diet could not produce the conditions necessary to raise the basal metabolism; hence the solution of this problem must be sought elsewhere, either in the environment or in heredity. In winter the temperature in Yucatan often ranges from 50° to 100° Fahrenheit. In spite of this extreme variation the Maya live in houses loosely constructed of poles and thatch, wear very meager cotton clothing and sleep in hammocks with no blankets. How this condition affects the metabolism is still to be determined.

The exhibit consisted of three panels: one showing the results of metabolism measurements; one very large one showing samples and models of various foods, samples and descriptions of actual meals and photographs illustrating the daily life of the Maya (Fig. 1); and the third panel gave a family chart and a few items on vital statistics. Lantern slides in a Balopticon illustrated farming practices and daily life of the people.

ARCHEOLOGY OF THE GUATEMALAN HIGHLANDS

The geographical location of the Highlands of Guatemala is such that they probably have served as a contact place for the various aboriginal groups of Middle America. This locality, therefore, is of great importance for a historical study of the relations between the Maya and other Indian groups, a problem in which the Carnegie Institution of Washington is deeply interested. The results of last winter's excavation work in that locality were shown by the Department of Historical Research.

In the immediate vicinity of Guatemala City there is an assemblage of over a hundred large mounds named Kaminaljuyu or "Hills of the Dead," marking the ceremonial center of what must have been a very populous community. One of these mounds was cut last winter to make way for a football field. Part of a wall was thus laid bare, and this gave the first hint that important discoveries might be made by excavations in that region. Subsequent work revealed that

the mound is the remains of a rubble pyramid, the substructure of a temple which has entirely disappeared. Further digging disclosed within it, excellently preserved, the stuccoed walls of a smaller, older pyramid, which in turn covered a still smaller one. At the end of the season the side of the fourth pyramid was encountered. A series of tombs lying below and to the east of the superimposed pyramids suggests that funerary customs may have been involved in the erection of the successive increments of the complex.

The graves are vertical shafts, twelve to sixteen feet square by fourteen to sixteen feet deep. In each was found a skeleton of a male whose body, loaded with ornaments of jade, shell, iron pyrites and mica, had been placed, sitting cross-legged, in the middle of the floor. About the principal skeleton were piled offerings of pottery; and in the corners along the sides of the vault lay other skeletons without ornaments, doubtless slaves sacrificed at the time of interment. Three tombs were cleared. Each shaft could be correlated with one of the three outer pyramids. It appears, therefore, that on the death of a person of importance, presumably a high-priest or a ruler, the temple of the cult with which he had been associated was dismantled and a new and larger shrine was built.

Some of the vases and effigies are allied to pieces recovered by the Institution from Maya tombs at Uaxactun, Guatemala; while others bear strong resemblance to pottery from the ruined city of Teotihuacan in central Mexico.

The exhibit consisted of photographs of the site in the Kaminal-juyu region, of full-sized paintings of pottery in original colors and of models of pottery.

Pinocytosis—the Drinking of Fluids by Cells

This new term, signifying the drinking by cells of globules of the fluid which bathes them, corresponds to the term phagocytosis, eating by cells of solid and semi-solid particles. This new process was discovered by Dr. Warren H. Lewis, of the Department of Embryology, Baltimore, while he was studying the motion pictures of macrophages, the highly mobile blood cells which live in the tissues. Pinocytosis became apparent when the motion pictures were viewed at the customary speed, about 50 times the rate at which they were taken.

Pinocytosis is carried on by ruffle pseudopodia which project here and there from the cell and undergo a continual wavy motion. The ruffles are exceedingly thin sheets of protoplasm thrust out from various regions of the cell. They are not permanent organs but appear and disappear constantly. As the ruffles wave about in the fluid medium which bathes them, they may entrap a little of the surrounding fluid and, by complete fusion of a portion of the ruffle about the fluid, convert it into an enclosed globule which is thus brought inside the cell. When the enclosed globule reaches the central part of the cell, it is rapidly digested.

The drinking by the macrophages cultivated outside sometimes continues steadily hour after hour over a period of several days, and they may drink many times their volume of fluid in the course of a day. Sometimes pinocytosis is intermittent and frequently no drinking appears to take place.

Pinocytosis has been observed only in cells cultivated outside the body and only on two types of normal cells: macrophages and, rarely, the fibroblast. Certain types of malignant sarcoma cells, however, show lively ruffle pseudopodia and active pinocytosis.

At this exhibit a motion picture was run at frequent intervals, accompanied by a short lecture. Under the microscope were shown living macrophages and cancer cells undergoing pinocytosis, and this

same process was shown on enlarged photo-transparencies.

The March of Forests in Response to Changing Climate

An exhibit dealing with this topic was prepared by Dr. Ralph W. Chaney, research associate of the Carnegie Institution and chairman of the Department of Paleontology of the University of California. Fossils from the United States, Northern Canada, Alaska, Siberia, China and Greenland show that during the Eocene period identical forest vegetation covered that whole section of the earth. During that period in regions now too cold to permit the growth of such trees, there lived redwood, beech, elm, ginkgo, magnolia and oak trees, all of whose modern descendants now live in lower latitudes where the climate is relatively mild. Not only did temperate forests of redwood and oak extend far north of the present tree line, but trees now characteristic of the tropics have been recorded from Eocene rocks of middle latitudes in the United States. The fig, avocado, bread-fruit and tree fern suggest a past climate in Tennessee and Oregon like that now found in Mexico and Central America. Heavy rainfall and an absence of frost must have contributed to the existence of such subtropical and tropical plants in these now temperate regions.

In the western United States, forests of the Miocene age were so much like those in higher latitudes during the preceding Eocene period as to indicate that most of their elements came down from the north. In the course of this journey they appear to have changed in many minor respects, but they still retained the redwood as a conspicuous member, together with other broad-leafed trees which were present in the older forests of Alaska. Though not definitely known, it is probable that east of the Rockies and north of Virginia there may have been a redwood forest similar to that of the Miocene period in Oregon.

The changing climate, resulting in plant migration southward from high to middle latitudes, may have been due in large part to the gradual rebuilding of North America and the rise of mountain ranges along the Pacific. The Cascades appear not to have been sufficiently high in early Miocene times to shut off rain-bearing winds from eastern Oregon. Since the Miocene period, further mountain uplift has made eastern Oregon a semi-arid plateau in which no trees may grow except in the most favorable localities. The redwood has been entirely eliminated and has survived only along the Pacific border, where summer fogs, combined with winter rains, provide a habitat sufficiently moist for this exacting tree.

The decrease in summer rainfall in western America has increased the number of trees with thick evergreen leaves and has reduced the representation of broad-leafed deciduous types. In such manner the forests of the eastern and western part of the United States, while arising at the same source and originally of the same composition, have come to bear distinctive characteristics.

The exhibit consisted of a collection of fossil leaves of fourteen species of trees. Next to each fossil leaf a modern leaf was placed showing clearly how little evolutionary change most of these species had undergone during a period of more than thirty million years. A four- to twelve-minute lecture, illustrated with lantern slides projected on maps showing the distribution of forests at different periods, was given at frequent intervals.

Protection and Use of a Primitive Natural Area at Point Lobos, California

The only remaining grove of Monterey cypress trees existing under primitive

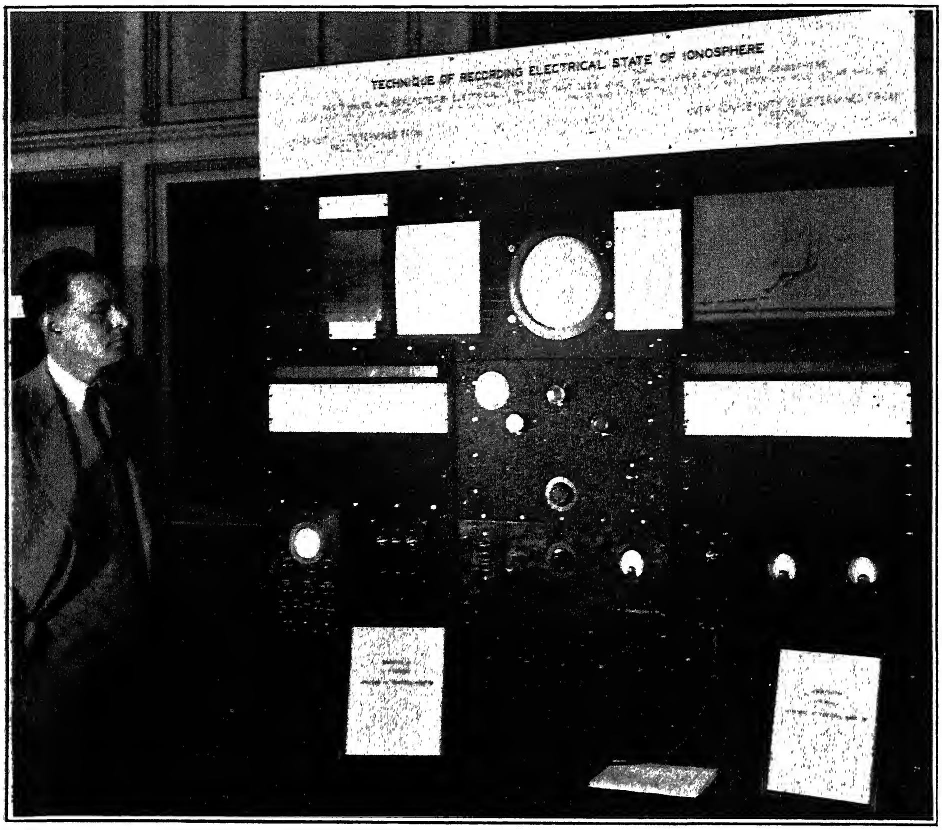


FIG. 2. AN ELECTRICALLY OPERATED PANEL
ILLUSTRATING THE RADIO-ECHO METHOD OF RECORDING THE ELECTRICAL STATE OF THE IONOSPHERE.

conditions is standing on a beautiful headland of the California coast near Monterey. In attempting to preserve this Point Lobos cypress grove it was necessary to have information regarding the contents of the grove and its environment. Exhaustive studies were made of the trees, all associated plants and animals, the soil, the rocks, the climate and the history of the region. Results of this study have been made the basis of the administration of the Point Lobos Reserve by the State of California.

The exhibit, prepared by N. B. Drury, of San Francisco, and Dr. R. W. Chaney, of the University of California, consisted of air photographs of the point, photographs of the groves and maps of the area.

Recent Cave Explorations in the Southwest

Caves have served as shelters for early man in America, and cavern deposits frequently contain evidence of man's occupancy. Remains of his fires, cultural objects and even skeletal parts make cave sites of special interest to the archeologist seeking to trace the history of man.

Specific sites containing evidence of man, animals and plants dating back in

time perhaps as much as 10,000 years are Shelter Cave, New Mexico, and Gypsum Cave, Nevada. In addition to facts bearing on the early history of man, a prevailing dry climate has brought about in some instances the preservation of the perishable parts of extinct animals not generally found in a fossil or subfossil record.

Explorations conducted in the lower Grand Canyon of Arizona under the auspices of the National Park Service have brought to light caves containing a remarkably well-preserved record of animal remains and in at least one instance an early Pueblo culture. The extinct ground sloth (*Nothrotherium*) is represented in the cavern accumulation not only by skull and skeletal parts, but also by dung, hide, hair, dried tissues and ligaments. Similarly preserved remains representing hoofed mammals and including apparently an extinct species of mountain goat (*Oreamnos*) have also been found. The occurrence has many points of similarity to the Gypsum Cave.

The exhibit prepared by Dr. Chester Stock, research associate of the Institution and professor of paleontology at the California Institute of Technology, showed skulls and skeletal parts, hide, hair and dung of various animals found in Rampart and Muav Caves in the lower Grand Canyon, in Smith Creek Cave and Gypsum Cave, Nevada, and Shelter Cave, New Mexico. Some specimens showed definite evidence of contact with heat or fire.

New Factors in Animal Metabolism

Metabolism signifies chemical changes proceeding continually in living cells, by which the energy is provided for the vital processes and activities, and new material is assimilated to repair the waste. When the body is relaxed and not actively digesting or absorbing food, the collective activity of the cells represents basal metabolism.

A long series of experiments revealed a significant difference in basal metabolism between different types of cattle and horses, types in which special functions had been developed to a high degree by selective breeding. The beef-cattle type, an energy conserver, has a low metabolism, while the dairy-cattle type, an energy secreter, has a high basal metabolism. Similarly, the draft horse has a low metabolism, while the race horse has a high metabolism.

In addition to the genetic factor responsible for the difference in metabolism another factor has been found. Experiments with cows indicated that the basal metabolism is highest in the spring, the percentage for different individuals ranging from 3 to 68 per cent. It is probably a significant fact that this seasonal effect, which appears to be independent of food intake, represents the highest general tissue stimulation during the period of longest and most intense sunlight. This contradicts the conception heretofore accepted that basal heat production is conditioned by the rate of heat loss.

The exhibit was prepared by Professor E. G. Ritzman, research associate of the Institution and a staff member of the New Hampshire Agricultural Experiment Station. It represents cooperative work with Dr. F. G. Benedict, of the Institution's Nutrition Laboratory at Boston. The exhibit consisted of charts with photographs of types of cattle and horses used in the experiments; data showing the number of calories used by these animals for different purposes; basal metabolism data; data on the influence of environment on metabolism; and photographs of apparatus used in the experiments.

Exploration of the Earth's High Atmosphere with Radio Waves

Rapid changes in the earth's magnetism, severe difficulties in long-range

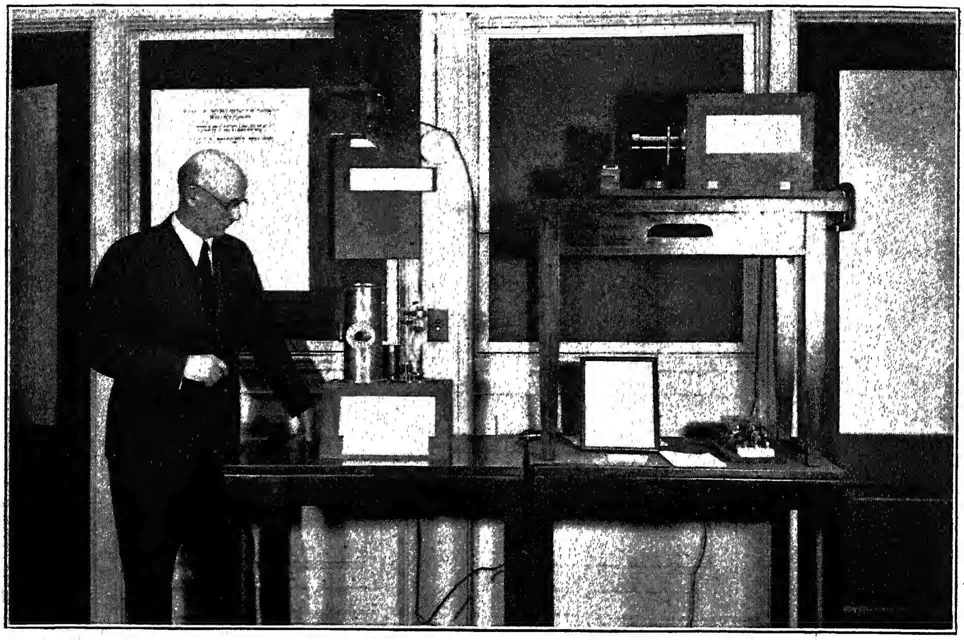


FIG. 3. A PHOTO-ELECTRIC PHOTOMETER
USED AT MT. WILSON OBSERVATORY FOR MEASUREMENTS OF ABSORBING MATERIAL IN SPACE.

radio transmission and effects observed in other branches of science arise in the outer region of the earth's atmosphere, which extends from 40 to 400 miles. They arise because of important physical and photochemical reactions in the upper atmosphere produced by conditions on the sun.

To understand the nature of the relationship between the solar causes and the consequent terrestrial manifestations, knowledge of the outer atmosphere is essential. With this problem in view, the Department of Terrestrial Magnetism at Washington has developed an apparatus which continuously and automatically records the electrical state of the upper atmosphere throughout its extent.

When a wave of certain radio frequency is transmitted upward it is reflected in the upper atmosphere only when it reaches a region having a definite density of ions. The time involved for the waves to travel upwards and to return to the ground is a few ten-thousandths of a second. The new apparatus automatically sends out short pulses of radio waves and registers their echoes, while the radio frequency is changed during a period of fifteen minutes from about 500 to 16,000 kilocycles per second. This procedure is repeated throughout the twenty-four hours of the day, so that changes in amount and distribution of ionization with respect to height can be continually measured.

The exhibit prepared by Drs. L. V. Berkner and H. W. Wells consisted of the actual apparatus and an electrically operated panel illustrating the principles of its operation (Fig. 2).

Absorbing Material in Space

The universe as now known is a vast space approximately a billion light-years in diameter, in which galaxies are, on the whole, uniformly distributed. The galaxies are in general separated from each

other by distances of the order of ten to a hundred times their own diameter, so that only a very minute portion of space is occupied by them. A galaxy is a system made up of stars, millions of them, separated from each other by very large distances of tens of millions of times the diameter of a star.

Our sun is a member of one of these galaxies—the Milky Way. It is known from star counts in various directions that the Milky Way is roughly lens-shaped, with a diameter of perhaps 100,000 light years and a maximum thickness of something like one fifth to one tenth of this. The sun is at a considerable distance from the center but not very far from the median plane of the system.

The new knowledge about absorbing material in the space of our galaxy has contributed to this picture of the universe principally by reducing the inferred importance of our own system. At one time the Milky Way was considered large enough to contain all the nebulae. When these were determined to be independent external systems of stars, the Milky Way still held the predominant place and was thought to be perhaps five times as large in diameter as the next largest system. With the dimensions of our own galaxy revised on the basis of absorption to about one half the previous size, and the diameter of other galaxies found to be larger than were formerly measured, our own place in space is not nearly so unique as we formerly had good reason to believe.

At this exhibit Dr. Joel Stebbins, research associate of the Institution and director of the Washburn Observatory of the University of Wisconsin, demonstrated a photo-electric photometer with which measurements of absorbing material were made (Fig. 3). Dr. Sinclair Smith, of the Mt. Wilson Observatory of Carnegie Institution, demonstrated two models of galaxies, one of the Milky Way as it would look from a distance of 20,000 light years, and another a model of nine neighboring galaxies as they would look from a distance of two million light-years.

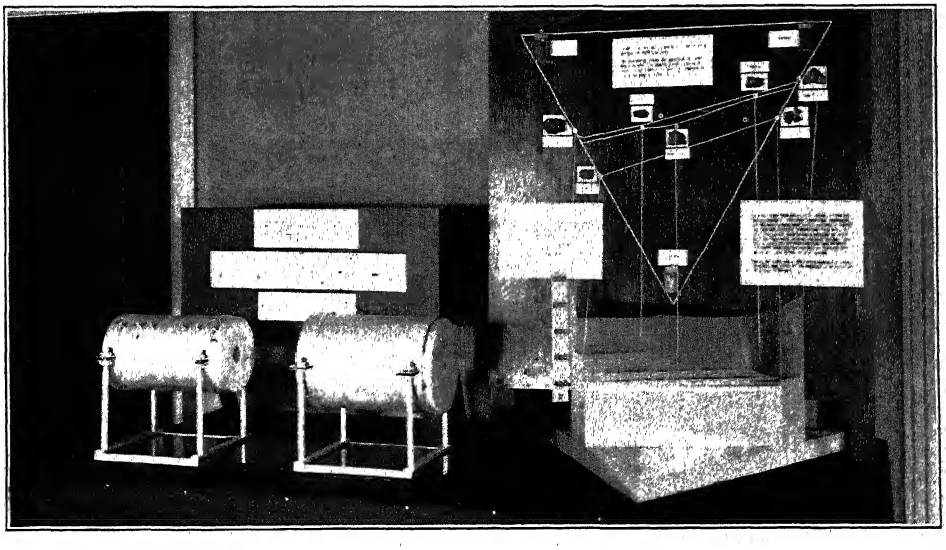


FIG. 4. THE SYNTHESIS OF ORES

FURNACES AND A TUBE USED AT THE GEOPHYSICAL LABORATORY FOR THE SYNTHESIS OF COPPER-IRON-SULFUR ORES, AND A CHART SHOWING THEIR PHYSICO-CHEMICAL INTER-RELATIONSHIPS.

Formation of Copper Ores

In many ore deposits throughout the world the indispensable element copper is associated with iron and sulfur. The elements are combined in a series of minerals; some of these minerals are found in large amounts in certain ore bodies, others are less common but still useful to students of ore deposits as clues to the occurrence of their more important relatives.

In nature the history of copper and iron sulfides goes back to volcanic and other phases of igneous activity. When the great bodies of igneous materials in the earth's crust cooled and crystallized, the sulfides of copper and iron separated from them more or less thoroughly. For many years the formation of ores has been studied intensively at the Geophysical Laboratory of Carnegie Institution at Washington, and as a result of these studies it is possible to prepare under defined conditions of temperature and pressure all the known natural copper-iron-sulfur minerals.

The exhibit prepared by Dr. H. E. Merwin, of the Geophysical Laboratory, consisted of ovens and tubes used in actual experiments; a generic chart of copper-iron-sulfur minerals indicating their interrelationships; and samples of these minerals (Fig. 4).

The Publications of the Institution

Since its inception the Institution has published the Year Book, of which the current issue constitutes the thirty-fifth volume of the series. These Year Books consist of comprehensive review of the current work of the various groups of investigators and a statement by the president explaining and interpreting the work of the Institution viewed as an organic whole.

Monographic series, with the first volume printed in 1903, record the results of large research projects. So far 687 volumes, aggregating 205,000 printed pages, have been published.

In order to disseminate interpretations of the scientific results among non-specialized readers as well as among scientists generally, the Institution has been publishing since 1926 the *News Service Bulletin*, the *Supplementary Publications Series* and the *Clip Sheet Service*.

Through the medium of the News Service Bulletin, articles dealing with important phases of current research and written in non-technical language are issued. The Supplementary Publication Series publishes the articles represented by lectures given under Institution sponsorship by staff members of the results of their investigations. The Clip Sheet Service is designed for the use of the press.

This exhibit consisted of a collection of various publications and especially those published during the current year.

POETRY AND ASTRONOMY

By Dr. FREDERICK W. GROVER

PROFESSOR OF ELECTRICAL ENGINEERING, UNION COLLEGE, SCHENECTADY, N. Y.

Poets and prose writers alike make frequent use of material descriptive of the natural world around us. Joyous and festive occasions require for their proper setting beautiful landscapes, the song of birds, gently rounded cloud forms. Villainous deeds, on the contrary, are never so villainous as when nature connives with forked lightnings, the sighing of the tempest and the prowling of unclean beasts to show them in their proper guise.

The beauties of the sunset sky have taxed the powers of poet as well as painter. How natural that the aspects of the heavenly bodies, the sun, the moon and stars should also receive literary treatment! Here, however, many writers show that they are on unfamiliar ground. Their figures of speech are obvious: their coloring is crude. Others, on the contrary, have understood how to weave astronomical fact with mythological legend to produce a fabric harmonizing with the action of the story or the mood of the actors.

The author has been interested for some years in noting such astronomical references in poetry as have come to his notice, and, although such a method of survey is far from comprehensive, many striking and beautiful passages have come to his attention. From these have been selected for quotation in this article examples of the best of this type of writing, gems distinguished not for their form and intrinsic beauty alone, but for the accuracy of their statement and their harmony with their settings.

References to those poetical descriptions of the constellations which have come down to us from classical times are here purposely omitted, as well as passages from that able and accurate account of astronomical discovery which Alfred Noyes has given us in "Watchers of the Sky." Such works lie beyond the scope of this article, which is to deal with astronomical allusions in poetry rather than with treatises on descriptive astronomy in poetical form.

Quotations from certain other authors are here omitted, because, in the judgment of the author, their astronomical interest is negligible. For example, Shelley's works abound in descriptions of beautiful clouds and gorgeous sunsets, but the heavenly bodies are either merely mentioned or introduced in an artificial manner. Swinburne's astronomical references are vague and his figures mixed. In still other poems, as, for example, Lytton's "When Stars are in the Quiet Skies," all the astronomical content is to be found in the title, and the poem is a love-lyric pure and simple.

On the other hand, the works of certain other writers, and preeminently those of Dante, Milton and Tennyson, contain frequent passages which argue the possession by their authors of considerable astronomical knowledge. Quite naturally, therefore, extracts from these authors will here receive especial prominence.

References to the sun are of frequent occurrence and depict it in various aspects. In the words of the Psalmist, he "is like a bridegroom coming out of his chamber, and rejoiceth as a strong man to run a race." Appropriate to this aspect also is the well-known stanza from

Omar Khayyam, in which is pictured the paling of the stars at dawn and the first moments of the sunrise:

Wake! For the Sun who scattered into flight
The stars before him from the fields of night,
Drives night along with them from Heav'n, and strikes
The Sultan's turret with a shaft of light.

The sun is often identified with the sun-god of mythology, who daily drove his chariot across the sky, and at night returned to the east below the ocean's rim. Thus Milton wrote of the sunset and the passage of the sun below the horizon in the north,

And the gilded car of day
His glowing axle doth allay
In the steep Atlantic stream:
And the slope sun his upward beam
Shoots against the dusky pole,
Pacing toward the other goal
Of his chamber in the east.

In quite another guise the same author depicts the sun at its rising:

So when the sun in bed,
Curtained in cloudy red,
Pillows his chin upon an orient wave.

Longfellow appropriately introduces the rising sun on the wedding morning of John Alden and Priscilla in the form of a high priest of Israel. References to the vestments prescribed by the law of Moses are skilfully introduced.

Forth from the curtain of clouds, from the tent of purple and scarlet,
Issued the sun, the great High-Priest, in his garments resplendent,
Holiness unto the Lord, in letters of light on his forehead,
Round the hem of his robe, the golden balls and pomegranates,
Blessing the world he came, and the bars of vapor beneath him
Gleamed like a grate of brass, and the sea at his feet was a laver.

References to the sun in eclipse are frequent. The ancient superstitious awe, evoked by that phenomenon, is touched upon in the following lines from "Paradise Lost":

. . . as when the sun new-risen
Looks through the horizontal misty air
Shorn of his beams, or, from behind the moon,
In dim eclipse, disastrous twilight sheds
On half the nations, and with fear of change
Perplexes monarchs.

The total eclipse of 1820, which Wordsworth saw in Italy, inspired one of his poems. His description of the unearthly illumination, which those of us who saw the eclipses of 1925 and 1932 will never forget, has an authentic ring which other parts of the poem do not possess.

The sky an azure field displayed;
'Twas sunlight sheathed and gently charmed,
Of all its sparkling rays disarmed,
And as in slumber laid—

Or something night and day between,
Like moonshine, without shadow, spread
On jutting rock and curved shore,—

The origin of the zodiac, that belt of constellations which marks the apparent path of the sun among the stars during the year, antedates history. The old familiar figures, beginning with the Ram and ending with the Fishes, which greet the eye from every almanac, have caught the imagination of many a poet, and are used by them to fix the seasons. Thus, for example, Longfellow describes the advance of the autumn at the end of October in the words

Now had the season returned, when the nights grow colder and longer,
And the retreating sun the sign of the Scorpion enters;

and Dante refers to the turn of the Italian winter, at the end of January, in a stanza which suggests the uncertain weather which there accompanies the lengthening of the days:

In the year's early nonage, when the sun
Tempers his tresses in Aquarius' urn,
And now towards equal day the nights recede;
When as the rime upon the earth puts on

Her dazzling sister's image, but not long
Her milder sway endures:

In his "Poet's Calendar" Longfellow gives verses descriptive of all the signs, and in Thomson's "Seasons" especially fine use of them is made. Thus, for example, the short northern night, at the end of June, is described, when the sun leaves the sign of Gemini and enters Cancer. In England, at that time, the twilight persists practically the whole night.

When now no more the alternate Twins are fired,
And Cancer reddens with the solar blaze
Short is the doubtful empire of the night.

This contrasts vividly with his picture of the opposite period of the year. In northern latitudes the December sun attains only a small altitude all the day.

Now when the cheerless Empire of the sky
To Capricorn the Centaur-Archer yields
And fierce Aquarius stains the inverted year;
Hung o'er the farthest verge of heaven, the Sun
Scarce spreads o'er ether the dejected day.

As would be expected, the moon in all its aspects lends itself well to poetic description. Whittier describes the crescent phase in the words,

A young moon at its narrowest
Curves sharp against the darkening west.

In "The Blessed Damozel" of Dante Gabriel Rosetti occurs the figure:

the curl'd moon
Was like a little feather
Fluttering far down the gulf.

Longfellow in "The Masque of Pandora" likens the new moon to the scythe of Kronos, who finds his counterpart in the sky in the planet Saturn.

Blood-red, last night,
I saw great Kronos rise; the crescent moon
Sank through the mist, as if it were the scythe
His parricidal hand had flung far down
The western steeps.

Browning describes the everchanging phases of the moon, its waxing and its waning and its changing position in the sky, in the poem "One Word More."

Lo, the moon's self!
Here in London, yonder late in Florence,
Still we find her face, the thrice transfigured,
Curving on a sky imbrued with color,
Drifted over Fiesole by twilight,
Came she, our new crescent of a hair's breadth,
Full she flared it, lamping Samminiato,
Rounder 'twixt the cypresses, and rounder,
Perfect till the nightingales applauded.
Now, a piece of her old self, impoverished,
Hard to greet, she traverses the house roofs,
Hurries with unhandsome thrift of silver,
Goes dispiritedly—glad to finish.

Longfellow described the pale disk of the moon seen in daylight hours in the words,

In broad daylight, and at noon,
Yesterday I saw the moon
Sailing high, but faint and white
As a school-boy's paper kite.

And Tennyson in "The Lover's Tale" describes it still more aptly.

On the other side, the moon,
Half-melted into thin blue air, stood still,
And pale and fibrous as a withered leaf,
Not yet endured in presence of his eyes
To indue his luster;

The full moon rising and bathing the landscape in a flood of light is a favorite theme, and it is difficult to select from the abundance of references examples which shall be representative. The following is from Thomson's "Autumn":

Now through the passing cloud she seems to stoop
Now up the pure Cerulean rides sublime.
Wide the pale Deluge floats, and streaming mild
O'er the skied mountain to the shadowy vale,
While rocks and floods reflect the quivering gleam
The whole air whitens with a boundless tide
Of silver radiance, trembling round the world.

Contrast this with a reference to the fact that the full moon blots out all but the brightest stars in a well-known passage from Wordsworth's "Intimations of Immortality."

The Moon doth with delight
Look round her when the heavens are bare;

Many beautiful passages refer to the moon in her rôle of the goddess Cynthia or Diana. How delicately, yet how vividly, these lines from Spenser's "Epithalamium" call to mind a night when the moon is at the full, and is consequently above the horizon from sunset to sunrise.

Who is the same, which at my window peepes?
Or whose is that fair face that shines so bright?
Is it not Cinthia, she who never sleepes,
But walks about high heaven all the night.

Quite different, but graceful also, is Ben Jonson's "Ode to Diana" which begins with the stanza:

Queen and huntress, chaste and fair,
Now the sun is laid to sleep,
Seated in thy silver chair
State in wonted manner keep:
Hesperus entreats your light,
Goddess excellently bright.

Of the planets bright Venus has especially inspired the poets. As morning-star it was known to the ancients as Phosphor or Lucifer, and as evening-star as Hesperus or Vesper, before it was realized that a single body was appearing in a dual rôle. This is referred to by Tennyson in "In Memoriam."

Sweet Hesper-Phosphor, double name,
For what is one, the first, the last,
Thou like my present and my past,
Thy place is changed; thou art the same.

References to the morning-star are generally of a joyous nature. In the book of Job we read that "the morning-stars sang together." It is the herald of the dawn, whose office it is to dismiss the other stars before the rising of the sun. In Milton's poem "On the Morning of Christ's Nativity" occurs the stanza:

The stars with deep amaze,
Stand fixed in steadfast gaze,
Bending one way their precious influence.
And will not take their flight,
For all the morning light
Or Lucifer that often warned them thence;
But in their glimmering orbs did glow,
Until their Lord himself bespake, and bid them go.

and in Tennyson's "Maud" occurs an especially fine treatment of the coming of the dawn.

For a breath of the morning moves,
And the planet of Love is on high,
Beginning to faint in the light that she loves,
On a bed of a daffodil sky,
To faint in the light of the sun she loves,
To faint in his light,—and to die.

There is a wealth of material having to do with Hesperus, the evening star. Wolfram's "Ode to the Evening-Star" in "Tannhaeuser" springs at once to mind. A whole section of Thomas Campbell's poem "Caroline" is dedicated to the evening-star. Of this poem, in which the star comes out a poor second to Caroline, the following is perhaps best worth quoting in this connection:

Gem of the crimson-colored Even,
Companion of retiring day,
Why at the closing gates of Heaven,
Beloved star, dost thou delay?

Akenside also composed a florid "Ode to the Evening-Star," which begins:

Tonight retired the queen of heaven
With young Endymion stays:
And now to Hesper is it given
Awhile to rule the vacant sky,
Till she shall to her lamp supply
A stream of brighter rays.

Most frequently reference is made to the brief splendor of the star in the twilight sky which ushers in the night, as is illustrated in "Paradise Lost."

The sun was sunk, and after him the star
Of Hesperus, whose office is to bring
Twilight upon earth, short arbiter
'Twixt day and night, and now from end to end
Night's hemisphere had veiled the horizon round.

Effective use of the star is also made to suggest a mood of sadness. For example,

in Tennyson's "In Memoriam" occurs the passage:

> Sad Hesper o'er the buried sun
> And ready, thou, to die with him,
> Thou watchest all things ever dim
> And dimmer, and a glory done.

The remaining planets, with the exception of Mars, have received scant poetical mention. Thomson, it is true, wrote of the solar system as a whole (bounded by Saturn in his day):

> from the far bourne
> Of utmost Saturn, wheeling wide his round
> Of thirty years, to Mercury, whose disk
> Can scarce be caught by philosophic eye,
> Lost in the near effulgence of thy blaze.

As he accurately states, Mercury is seldom seen except by the astronomers. Saturn, although fairly bright, is not readily distinguished among the other brighter stars. It seems strange, however, that Jupiter has not received some poetic notice. For months at a time, every year, it is the brightest of the stars of the night sky and is not greatly excelled in brightness by Venus. Mars, on the contrary, although it is inconspicuous except for a few weeks every other year, has gained some mention among the poets, probably because of its fiery red color and the warlike associations of its name.

In Longfellow's poem, "The Light of Stars," "the first watch of the night is given to the red planet Mars." In Dante's "Inferno" occurs the passage

> And now, behold! as at the approach of morning,
> Through the gross vapors, Mars grows fiery red
> Down in the west upon the ocean floor.

An interesting reference to Mars from a historical point of view is found in Tennyson's "Maud."

> She seemed to divide in a dream from a band of the blest,
> And spoke of a hope for the world in the coming wars—
> "And in that hope, dear soul, let trouble have rest,
> Knowing I tarry for thee," and pointed to Mars
> As he glowed like a ruddy shield on the Lion's breast.

The reference is to the entry of England into the Crimean War, 1854–55. Calculation shows that Mars came to opposition (maximum brightness) in the spring of 1853 in the constellation of the Lion close to Regulus, the bright star which marks the heart of the Lion.

The starry heavens themselves have inspired a variety of poetic images. Longfellow in "Evangeline" likens the stars to "the forget-me-nots of the angels," and farther on in the same poem to "the thoughts of God in the heavens." In "Sandalphon" he gives a moving description of the beauties of a clear, moonless night in the lines:

> When I look from my window at night,
> And the welkin above is all white,
> All throbbing and panting with stars.

In the so-called Greek Hymn the stars are themselves angels, and so are they named in Lowell's "Rosaline."

> The stars came out; and one by one,
> Each angel from his silver throne
> Looked down and saw what I had done.

References to the Milky Way are summarized in Longfellow's "Galaxy." From this may be quoted a passage which contrasts the usual, the classic connection of the Galaxy with the legend of Phaeton with a conception which is all the poet's own.

> Nor this I see, nor yet the ancient fable
> Of Phaeton's wild course, that scorched the skies
> Where'er the hoofs of his hot coursers trod;
> But the white drift of worlds o'er chasms of sable,
> The star-dust, that is whirled aloft and flies
> From the invisible chariot-wheels of God.

The silent, unhastening, ceaseless march of the stars from their rising to their setting lends itself well to the mark-

ing of the passage of time for the poets as well as for the astronomers. In Dante's great work the transition from one episode to another is often effected by the interpolation of a passage describing the positions of certain constellations, for example, the interpolation at the end of Canto XI of the Inferno:

> . . . for now
> The Pisces play with undulating glance
> Along the horizon, and the Wain lies all
> O'er the northwest; and onward there a space
> Is our steep passage down the rocky height.

This aspect of the sky corresponds to a time about two hours before the sunrise on April 9 (the date of Good Friday in 1300.)

In "Cassandra Southwick" Whittier gives a picture of hours spent in weariness of spirit.

> Last night I saw the sunset melt through my prison bars,
> Last night across my damp earth-floor fell the pale gleam of stars:
> In the coldness and the darkness, all through the long night-time
> My grated casement whitened with the autumn's early rime.
> Alone in that dark sorrow, hour after hour crept by,
> Star after star looked palely in and sank adown the sky.

Frequent and effective use is made of a figure of speech, borrowed from the classical writers, which supposes the sun, moon and stars to rise from the sea and to be bathed, at their setting, in the waves of the western ocean, at the confines of the world. For example, in Tennyson's stirring poem "Ulysses" the ageless hero exhorts his comrades in the words:

> Come, my friends,
> 'Tis not too late to seek a newer world.
> Push off, and sitting well in order smite
> The sounding furrows: for my purpose holds
> To sail beyond the sunset, and the baths
> Of all the western stars, until I die.

It is generally conceded that the constellations date back to about 3000 B.C. To two of the classical writers, Aratus and Manilius, we owe full descriptions of them, together with accounts of their reputed influence on the weather and the connection of the times of appearance of certain of them with the times of sowing and reaping. The works of these authors, taken with the records of the positions of the brighter stars made by Ptolemy from his measurements, make it certain that the constellations are essentially unchanging through the centuries. The contrast between this fixity of the skies above us and the ephemeral nature of our lives and fortunes has often been made the theme of poetry. As an instance of this may be quoted that familiar passage from Omar Khayyam, which has been so effectively set to music in Lisa Lehmann's "Persian Garden":

> Yon rising moon that looks for us again—
> How oft hereafter will she wax and wane;
> How oft hereafter rising look for us
> Through this same garden—and for *one* in vain!

The same theme underlies also the following from "Lucifer and Elissa" by Philip James Bailey:

> . . . nigh one year ago,
> I watched that large bright star, much where it is now!
> Time hath not touched its everlasting lightning,
> Nor dimmed the glorious glances of its eye,
> Nor passion clouded it, nor any star
> Eclips'd: it is the leader still of heaven.
> And I who lov'd it then can love it now;
> But I am not what I was, in one degree.

Certain of the star groups and the brighter individual stars find mention in the works of many authors. Among them the stars Arcturus and Sirius, the two star clusters of the Pleiades and the Hyades, the constellations of Orion, the Greater Bear and the Smaller Bear are those most often cited. Thus, in the Book of Job, we find the passage, "Canst thou bind the sweet influences of the Pleiades, or loose the bands of Orion? Canst thou bring forth Mazzaroth (the signs of the

zodiac) in his seasons? Or canst thou guide Arcturus with his sons?"

The constellations of the Bears never set in northern latitudes but circle endlessly about the pole. This fact is referred to in the following quotation from the Odyssey:

So he sat and cunningly guided the craft with the helm
Nor did sleep fall upon his eyelids as he viewed
The Pleiades and Boötes, that setteth late, and
The Bear, which they likewise call the Wain, which
Turneth ever in one place and alone hath no
Part in the baths of Ocean.

In "Balder Dead" Matthew Arnold writes in a similar vein:

But he must ever watch the Northern Bear,
Who from her frozen heights with jealous eye,
Confronts the Dog and Hunter in the south,
And is alone not dip't in Ocean's stream.

And in "Prometheus" Lowell has produced a beautiful sequence of astronomical figures:

The Bear, that prowled all night about the fold
Of the north-star, hath shrunk into his den,
Scared by the blithesome footsteps of the Dawn,
Whose blushing smile floods all the Orient;
And now bright Lucifer grows less and less
Into the heavens' blue quiet deep-withdrawn.

The practically fixed position of the pole-star in the sky and its usefulness in navigation is referred to in the following passage by William Cullen Bryant.

On thy unaltering blaze
The half-wrecked mariner, his compass lost,
Fixes his steady gaze,
And steers undoubting to the friendly coast;
And they who stray in perilous wastes by night
Are glad when thou dost shine to guide their footsteps right.

The lines which Lowell puts into the mouth of Columbus liken the star to a lighthouse:

This have I mused on, since mine eye could first
Among the stars distinguish and with joy
Rest on that God-fed Pharos of the north,
On some blue promontory of heaven lighted
That juts far out into the upper sea.

The constellation Orion, the most conspicuous in the sky, forms the subject of the poems "The Occultation of Orion," by Longfellow, "Singing Stars," by Arthur Reed Ropes, and "Orion," by Charles Turner. Tennyson in "Maud" showed his familiarity with the constellation in the beautiful and accurate picture which he drew of the western sky in the month of May.

For it fell at a time of year
When the face of the night is fair on the dewy downs,
And the shining daffodil dies, and the Charioteer
And starry Gemini hang like glorious crowns
Over Orion's grave low down in the west.

Effective emphasis of the distance which separates us from those living in the Antipodes is afforded by references to the differences of their seasons from our own and the changed aspect of the sky seen in southern latitudes. In "The Brook," by Tennyson,

Katie walks
By the long wash of the Australasian seas
Far off, and holds her head to other stars,
And breathes in converse seasons.

South of the equator our pole star is continually below the northern horizon, while the famous Southern Cross circles about the region where a few faint stars mark the south pole of the heavens. These differences are used with telling effect in a poem by Housman entitled "Astronomy":

The Wain upon the northern steep
Descends and lifts away.
Oh I will sit me down and weep
For bones in Africa.

For pay and medals, name and rank,
Things that he has not found,
He hove the Cross to heaven and sank
The pole-star underground.

And now he does not even see
Signs of the nadir roll

At night over the ground where he
Is buried with the pole.

However, perhaps the most remarkable reference to the Southern Cross to be found in the literature occurs in Dante's "Purgatorio." After having discussed with his guide and mentor the to him unfamiliar motion of the sun from right to left in the northern sky, brought about by their position south of the equator, Dante, a little farther on, refers to the aspect of the night sky:

To the right hand I turn'd, and fixed my mind
On the other pole attentive, where I saw
Four stars ne'er seen before save by the ken
Of our first parents. Heaven of their rays
Seem'd joyous. O thou northern site bereft
Indeed, and widow'd, since of these deprived.

The reference to the four stars of the Cross is unmistakable. When the constellations were first named, millenniums before the Christian era, the Southern Cross was visible in the north temperate zone, but the slow precession of the earth's axis, during the centuries, has brought about great changes in the positions of the poles among the stars. The Southern Cross is now always below the horizon, except for places in the tropics and the southern hemisphere, and such was the case also in Dante's time.

The poetic quotations thus far considered all relate to what may be termed the astronomy of the ancients, that is, the astronomy of the millenniums before the invention of the telescope and the application of exact measuring instruments to the study of the sky revolutionized astronomical progress. For the most part, the astronomical figures found in the works of modern poets with their mythological allusions are merely variants of those used by the classical writers, and this is quite appropriate. In spite of the existence of astronomical observatories, most of us continue to view the beauties of the sky without optical aid, as did our forefathers, and like them take pleasure in the legends associated with the heavenly bodies. It is popularly believed, indeed, that exact science and poetry are mutually exclusive in any work, and it is true, of course, that scientific books make little or no use of the medium of poetry in imparting knowledge. Certain poets, however, have been so successful in combining scientific accuracy with beauty of diction as to argue for them the possession of a knowledge of astronomical science. Examples have already been given which indicate that Dante was well versed in the astronomical lore of his time. In "Paradise Lost" are to be found many passages in which the astronomical ideas of the Copernican theory, which was becoming firmly established in Milton's time, are compared with those of the older, artificial Ptolemaic system, which dealt with a celestial sphere

With Centric and Eccentric scribbled o'er
Cycle and Epicycle, orb in orb.

In the same work Uriel is made to argue the merits of the two systems at some length. That the discoveries of Galileo with his newly invented telescope were well known to Milton is evidenced by the passage in which he describes Satan's shield:

The broad circumference
Hung on his shoulders like the moon, whose orb
Through optic glass the Tuscan artist views
At evening, from the top of Fesolé
Or in Valderno, to descry new lands,
Rivers, or mountains, in her spotty globe.

Until modern times, the apparition of a comet suddenly appearing out of the nowhere was believed to presage the death of some important personage or some other dire calamity. Shakespeare voices that belief in "Julius Caesar":

When beggars die, there are no comets seen;
The heavens themselves blaze forth the death of princes.

A comet which appeared in 1066 was afterward believed to have foretold the

Norman Conquest. In the poem "Harold" Tennyson represents Morcas as saying,

"Lord Leodwin, dost thou believe that these
Three rods of blood-red fire up yonder mean
The doom of England and the wrath of heaven?"

The comet of 1456 preceded the deposition and subsequent execution of the unfortunate Henry VI. This event probably suggested the following lines from Shakespeare's drama of that name:

Comets, importing change of times and states
Brandish your crystal tresses in the sky;
And with them scourge the bad, revolting stars
That have consented unto Henry's death.

The English astronomer, Halley, reasoning from the similarity of the calculated orbits, dates of appearance and recorded aspects of certain remarkable comets of the past, came to the conclusion that the great comet of 1682 would return in 1758. Actually, the comet reappeared only a few months later than the predicted date, but more than twenty years after the death of Halley. It was this same comet, whose elongated elliptical orbit is well known to present-day astronomers which was given such publicity in 1910. That the verification of Halley's prediction made a deep impression on the poet Thomson is evident from a number of passages of which the following is perhaps the best:

Lo! from the dread immensity of space,
Returning with accelerated pace,
The rushing comet to the sun descends:
And, as he shrinks below the shading earth,
With awful train projected o'er the heavens
The guilty nations tremble.

Contrast this with the verses previously quoted above. The element of fear is still retained, but the rapid increase in the velocity of the comet as it approaches the sun, a characteristic of motion in an elongated elliptical orbit, as well as the very close approach of the comet to the sun are skilfully treated.

In the last century, Longfellow, and still more so, Tennyson, give evidence that they were interested in the progress of science. In "Locksley Hall" Tennyson probably referred to this when he wrote,

Here about the beach I wandered, nourishing a youth sublime
With the fairy tales of science, and the long result of time.

Browning, in general, discloses no such interest, but in "One Word More" he makes ingenious use of the fact that the moon constantly keeps the same face turned toward us, the other side being perpetually invisible from the earth.

What, there's nothing in the moon noteworthy?
Nay—for if that moon could love a mortal,
Use to charm him (so to fit a fancy)
All her magic ('tis the old sweet mythos)
She would turn a new side to her mortal,
Side unseen of herdsman, huntsman, steersman—
Blank to Zoroaster on his terrace,
Blind to Galileo on his turret,
Dumb to Homer, dumb to Keats—him, even!

And a few lines farther on,

God be thanked, the meanest of His creatures
Boasts two soul-sides, one to face the world with,
One to show a woman when he loves her.

The discovery of the planet Neptune in 1846 as a result of a mathematical study of perturbations of the motion of the planet Uranus, inspired, no doubt, the following passage from Longfellow's "Haunted Houses":

These perturbations, this perpetual jar
Of earthly wants and aspirations high,
Comes from the influence of an unseen star,
An undiscovered planet in our sky.

The lines of Keats,

Then felt I like some watcher of the skies
When a new planet swims into his ken,

refer to the discovery of Uranus, in 1781, an event resulting not from diligent theoretical investigation, but from Herschel's tireless telescopic exploration

of the sky. The wording is a little fanciful, since the newly found object was not at first recognized for what it was, so little did he or any one else suspect the existence of undiscovered planets.

In "Christus: A Mystery," Longfellow concisely and accurately refers to the double stars, stars which appear so close together in the sky that telescopic aid is necessary to see them separated.

> Nor let the Historian blame the poet here,
> If he perchance misdate the day or year,
> And group events together, by his art,
> That in the Chronicles lie far apart;
> For as the double stars, though sundered far,
> Seem to the naked eye a single star,
> So facts of history, at a distance seen,
> Into one common point of light convene.

The same poet, in "Charles Sumner," makes effective use of the fact that the stars are so distant that the light leaving the star at any moment does not reach the earth until years later.

> Were a star quenched on high,
> For ages would its light
> Still traveling downward from the sky
> Shine on our mortal sight.
>
> So when a great man dies
> For years beyond our ken
> The light he leaves behind him lies
> Upon the paths of men.

The question whether life exists on other planets of our solar system besides the earth will probably never be certainly answered. In the light of the evidence available, astronomers believe that Mars and Venus only may offer conditions not wholly inhospitable. From those planets the earth must appear as a star of much the same brightness as Venus appears to us. Tennyson, in "Locksley Hall Sixty Years Later," has ingeniously introduced these facts in the following passage:

> Venus near her! smiling downward at this earthlier earth of ours
> Closer on the sun, perhaps a world of never fading flowers.
> Hesper, whom the poet call'd the Bringer home of all good things.
> All good things may move in Hesper, perfect peoples, perfect kings.
> Hesper—Venus—were we native to that splendor or in Mars,
> We should see the Globe we groan in, fairest of their evening stars.
> Could we dream of wars and carnage, craft and madness, lust and spite
> Roaring London, raving Paris, in that point of peaceful light?
> Might we not in glancing heavenward on a star so silver-fair,
> Yearn and clasp the hands and murmur, "Would to God that we were there?"

The famous cluster of stars which bears the name of the Pleiades has been an object of interest since the earliest times. Every one can make out six stars, and some people three or four more. Galileo with his tiny telescope was able to see forty-five stars; large telescopes bring out hundreds. The surprising fact, however, is that when, first, photographs of the cluster were taken in the eighties of the last century, it was discovered that the stars are involved in an extended mass of nebulosity, that is, in a misty, ill-defined cloud of

> white nebulous matter between stars,
> Which, if not light, at least is likest light,

as Philip James Bailey so aptly describes it. A particularly happy description of the Pleiades, suggesting both the clustering stars and the nebulous cloud in which they are involved, is found in "Locksley Hall":

> Many a night I saw the Pleiades, rising through the mellow shade,
> Glitter like a swarm of fireflies tangled in a silver braid.

In "The Golden Year" Tennyson refers to the motion of the sun through space, a motion which is taking it, together with the planets which revolve

around it, toward the constellation of Hercules.

We sleep and wake and sleep, but all things move;
The Sun flies forward to his brother sun;
The dark earth follows wheel'd in her ellipse:

In "The Princess" occurs a passage inspired by the Nebular Hypothesis of Laplace. This hypothesis postulates the evolution of the stars from nebulous matter as a result of eddying motion and condensation resulting from it. Continued motion and further condensation cause the planets to be thrown off from the nascent suns. The quotation referred to is as follows:

This world was once a fluid haze of light,
Till toward the center set the starry tides,
And eddied into suns, that wheeling cast
The planets: then the monster, then the man.

And in his "Epilogue" occurs a stanza which embodies the modern idea of island universes, that is, of the existence of not one but many universes, our own the Galaxy, and the others visible to us as spiral nebulae.

The fires which arch this dusky dot—
Yonder myriaded-worlded way—
The vast sun-clusters' gathered blaze,
World isles in lonely skies,
Whole heavens within themselves.

The progress of science has never been so rapid as during the generation which has elapsed since the Victorian era: astronomical research has won for us a widely increased and ever growing knowledge of the starry heavens. However, to the best of the writer's knowledge, no poet has drawn inspiration from these new marvels, nor allowed his fancy to roam over this virgin field. Yet it would be a fascinating task, and one demanding no mean ability, to picture the whirl of the spectroscopic binaries, and the rhythmic oscillations of the Cepheid variables, to describe the individualities of the dwarf and giant stars, or to soar in imagination to the confines of an expanding universe.

THE BEGINNINGS OF HISPANO-INDIAN SOCIETY IN YUCATAN

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Factors Affecting Colonial Policy

Spanish colonial policy in America developed naturally from two basic factors: (1) conditions within the areas that were conquered and (2) the ideals and aims of the Spanish monarchy in the sixteenth century.

Although the Spanish colonies were for the most part within the tropical and sub-tropical zones, they contained large areas suitable for European settlement. Colonists in considerable numbers migrated to specially favored regions in New Spain and Peru, where they engaged in farming, stock raising, mining and trade. But the Spaniards found most of these areas already occupied by a numerous aboriginal population with highly developed civilizations based on an advanced agricultural economy. In this respect Hispanic America contrasted rather sharply with the temperate zones in which the British colonies in North America were founded, for the vast expanse of what is now the United States was lightly populated and the Indians were much less strongly rooted to the soil than those of Mexico, Guatemala and Peru. The British were able, therefore, to deal with the Indian tribes as independent units, as nations outside their own colonial system, whereas Spain was forced to incorporate them as an integral part of colonial society. Thus social evolution in Hispanic America has been characterized by the interaction and partial fusion of two races, and two sets of culture patterns, European and aboriginal.

The forces which influenced the formulation of policy dealing with the aborigines and their relations with the Spanish colonists were economic and religious, selfish and humanitarian. The original impelling motive of discovery and colonization was economic, and the exploitation of the resources of the colonies for the benefit of the Crown and of the colonists who supported the imperial system always remained the paramount factor in determining the character of administration. But the long crusade against the Moors had identified the cause of Catholic orthodoxy with national interests, and a militant zeal for the faith inspired the Spanish nation. It was inevitable, therefore, that when the Indies were conquered, the conversion of the aborigines and the extirpation of the older pagan religion and ceremonial should become one of the dominant aims of empire. Moreover, the Spanish jurists of the sixteenth century were inspired by a broad humanitarianism and an increasing interest in the relations between nations and peoples. The question of the aborigines raised important problems of theoretical and practical justice and the influence of the jurists contributed much to the formulation of legislation for the preservation of the liberties of the Indians within the limits imposed by the introduction of a new faith and the maintenance of Spanish supremacy.

The attempt to combine the economic and the ecclesiastico-humanitarian motives of empire created problems of tremendous historical significance. The Crown was obliged to recognize the demands of the colonists for the right to exploit Indian lands and labor, but it sought to limit abuses by protective legislation that would preserve at least the

legal status of the Indians as free beings and prevent the total expropriation of Indian property. It sought also to ensure the conversion of the Indians to the Christian faith, at the same time preserving the traditional folk culture in so far as it did not conflict with Christian standards of morals and orthodoxy. Hispanic America became in effect a sociological laboratory where experiments in human relationships were made on a vast scale. The final result was the creation of a Hispano-Indian society characterized by the domination of the masses by a small privileged minority, the hybridization of culture and the existence of unsolved problems of land and labor.

The History of Yucatan project sponsored by the Carnegie Institution of Washington is a part of its larger program of Maya research. Although the specific aim of the investigations in the post-conquest history of the Maya is to give unity to the researches of the specialists in Maya archæology on the one hand, and the descriptive studies dealing with modern folk culture in Yucatan on the other, these investigations become in reality a case study for the illustration of those problems of Hispanic-American social history that are derived from the conflict and fusion of cultures. The Carnegie Institution has made it possible to carry on the necessary spade work in the unpublished documentary sources in the archives of Spain and America, and it is hoped that the program, when completed, will provide a detailed analysis of Spanish colonial administrative processes as well as of theoretical policy and legislation in this important area.

The Hispano-Indian Government

The basic pattern of Hispano-Indian society in Yucatan was clearly marked out by the end of the sixteenth century or about sixty years after the conquest. By that time a new ruling caste of foreign origin, extremely jealous of its privileges, had obtained firm control over the destinies of the Maya race; the exploitation of Indian labor for the benefit of this caste had become an important problem of interracial relations; and a considerable amount of fusion of culture, especially in the realm of religion, had taken place. During the remainder of the colonial period these basic problems of provincial society remained essentially the same. The methods of exploitation of Indian labor changed according to the needs of the ruling class. The proportion of Christian and pagan elements in the total content of belief and ceremonial by which the Indians made their adjustments with the invisible world varied from place to place and from time to time. But there was no essential change in the fundamental character of Hispano-Indian society.

Several centuries prior to the Spanish conquest the Maya of Yucatan had established a measure of political unity. However, rivalry between the chieftains had caused the disintegration of central authority, and at the opening of the sixteenth century Yucatan was divided into a number of petty states or cacicazgos which frequently engaged in interstate warfare. Political leadership within each state tended to be concentrated in the hands of a ruling family, such as the Xius in Mani or the Cocoms in Sotuta. The unifying forces were cultural rather than political—a common language and a common fund of folk tradition.

The Spanish conquest destroyed the independence of these states and reestablished territorial and political unity within Yucatan, but the reins of government were held henceforth by an alien race. Supreme political and military authority was exercised by the Spanish governors appointed by the Crown. Subordinate to the governors were various local officers and the governing councils of the Spanish towns.

A measure of self-government was retained by the Maya in the Indian vil-

lages where local affairs continued to be controlled by native officers. In the beginning the Spanish authorities recognized the claims of former native lords and lesser nobles, and retained them as governors and principales of the pueblos. Moreover, during the sixteenth century certain chieftains even continued to exercise some leadership over areas that approximated the former petty states. But in the course of time the old rulers and their direct descendants were gradually removed from positions of influence and leadership.

This does not mean that the former ruling families lost all their old prestige. The Xius, for example, were recognized as having noble rank, and they obtained certain concessions and privileges, such as exemption from tribute, free labor on their farms and the right to possess firearms. They were also able to retain considerable holdings of land. But their influence as political and cultural leaders of the race was at an end.

The Ruling Caste

The real governing class in Yucatan subsequent to the conquest was a group of about 125 families, made up of conquerors, first settlers and their descendants. Members of this group held most of the subordinate provincial offices, and they dominated the city councils of Merida, Campeche and Valladolid, membership in which could be purchased and held for life. Control of the local councils gave the conquerors and their descendants the means for resisting measures limiting their vested rights. They were frequently able also to force the provincial governor or the defender of the Indians to abandon policies for the amelioration of abuses of native labor and other reforms detrimental to the interests of the ruling caste. Occasionally a provincial governor would try to strengthen his own position by the appointment of relations or personal retainers to local offices, but the conquistador caste would immediately present a forceful protest to the Crown and would usually be upheld. Special claims were also made on behalf of younger sons for preference in appointments to curacies in Indian towns and to offices in the cathedral of Merida.

In so far as possible the conquistadores sought to keep their blood clean, at least the line which inherited property. A few formally contracted marriage with Indian women, but most of the unions between the two races were extramarital. Mestizo children born out of wedlock were sometimes legitimized, but the ruling caste used all its influence to prevent them from holding office.

Encomiendas

The most important privilege granted to the conquerors and their descendants in all parts of the Indies was preference in appointment to encomiendas. During the first half of the sixteenth century an encomienda grant was essentially the right to use the labor of a stated group of Indians without pay. But this led to such abuses that a fixed tribute usually payable in kind was introduced in lieu of service, with the result that the encomiendas became a form of pension. The encomenderos were always able, of course, to obtain a considerable amount of labor from their Indians by extra-legal means, but subsequent to 1550 the essence of the system was tribute.

In return for the tribute payments the encomenderos were supposed to assume responsibility for the indoctrination of their Indians, but this obligation became a mere formality in so far as personal assistance in the missionary program was concerned. The most important obligation imposed by a grant of encomienda was military service, and in Yucatan the encomenderos were frequently called upon to defend the coasts or the port of Campeche against foreign corsairs. Grants of encomienda were made for two

lives or generations, but a third life was usually permitted by dissimulation on the part of the governing officials.

In Mexico proper, *i.e.,* in the area northwest of the Isthmus of Tehuantepec, about 55 per cent. of the Indian pueblos were held in encomienda, the remaining 45 per cent. paying tribute to the Crown. In Yucatan more than 90 per cent. of the towns were granted as encomiendas. This fact may be explained by the limited resources of Yucatan and the lack of opportunity for profitable enterprise other than agriculture. There were no mines; trade was limited mostly to dealings in those very native products of which the tribute payments were comprised, *viz.,* cotton cloth, maize, poultry and wax. In the sixteenth century grants of encomienda were practically the only means available for gratifying services performed during the conquest or for attracting new settlers to the province.

It is not surprising, therefore, that there was keen rivalry for appointments to encomiendas, that the tendency of a governor to fill vacancies by choosing new arrivals in preference to members of the old families was always bitterly resisted, or that protests were made against every attempt by the Crown to bring the system to an end. Grants of encomienda continued to be made until 1785, when the Crown finally ordered all tributes to be paid into the treasury, but even then payments continued to be made to former holders of encomiendas during the remainder of their lives.

Value of Tribute Required

The value of the encomienda tributes varied considerably from time to time. In the beginning the levies were based on the number of married males, with certain exceptions for persons who enjoyed freedom from tribute for one reason or another, but in the 1580's unmarried and widowed adults were also included in the matriculas or tribute rolls, with an assessment of one half the amount paid by a married person. The tributes were payable in kind. At first a large variety of articles, such as cotton cloth, maize, poultry, wax, honey, salt, fish, pottery, chile, beans, etc., were included in the village assessments, but by the end of the sixteenth century only three staples were required, *viz.,* cotton cloth, maize and poultry. In 1606 each married tribute payer was assessed about six square yards of cotton cloth, about 150 pounds of maize, one turkey and one chicken annually. There was also a considerable variation in prices between 1540 and 1600. The full unit of assessment during this period seems to have been worth amounts varying from twenty-three to thirty-six reales, depending on prices and the amount of goods payable annually. The 1606 assessment was worth thirty-one reales, or three and seven eighths silver pesos.

It is difficult to make an estimate of the value of the annual tribute payments in terms of modern currency. Any true estimate would depend upon the purchasing power of the old Spanish silver peso as compared with that of the modern Mexican peso. Maize prices probably provide the best basis for estimating purchasing power, and it appears that in 1606 the Spanish peso would buy at least four or five times as much maize as the present Mexican peso. On this basis the value of the annual tribute assessment for each married tribute payer in 1606 was 15.5 to 19.4 pesos in terms of modern purchasing power.

A conservative estimate of the value of encomienda tributes in 1549 would be 210,000 pesos. In 1606 they amounted to approximately 160,000 pesos. The largest encomienda in 1606 produced a gross revenue of 6,200 pesos, and the smallest 155 pesos. The average gross revenue was about 1,350. These sums should be multiplied by four or five to give the approximate purchasing power in Mexican pesos at present. The aver-

age gross income of about 1,350 pesos was a very generous sum, especially if we compare it with the governor's salary of 1,000 gold pesos or about 1,600 in silver.

The average wage for unskilled Indian labor was probably not more than one half a real or one sixteenth of a peso per day. For example, in 1553, the clergy and the city council of Merida agreed to fix wages at the following schedule: (1) two reales a week plus food for ordinary labor; (2) four reales a month for house servants or permanent employees receiving food and clothing; (3) twenty grains of cacao a day for porters carrying maize to Merida, a day's journey to be counted as five leagues. At current prices in 1553 this amount of cacao would have been worth no more than one fifth of a real, probably less. In the 1570's common labor received 300 grains of cacao per week, or between two and three reales. In 1578 carpenters working on the cathedral of Merida were paid one real a day. Thus one half a real per day may be regarded as a fair estimate of wages for unskilled labor. The value of the individual tribute assessment varied from twenty-three to perhaps thirty-six reales. At one half a real a day for current wages, the tribute assessment would represent forty-six to seventy-two days of labor, a truly astonishing figure!

The Tribute an Excessive Burden

The excessive burden of the tributes is indicated also if we try to arrive at some estimate of what the unit of assessment represented in terms of maize consumption. In 1606 the total value of the assessment for a married adult was thirty-one reales. Maize in that year was valued at four reales for about seventy-five pounds. The total assessment represented, therefore, the value of about 580 pounds of maize. Steggerda has found that at the present time the average consumption of maize per person is about 1.33 pounds per day, or for a family of five about 6.7 pounds. The 1606 assessment for the head of a family considered in terms of maize would, therefore, provide for the needs of a family of five for eighty-seven days. We can not be sure that the consumption of maize per person or per family was the same in 1606 as at present, but in view of the fact that maize has always been the most important article of diet, the variation would not have been great.

But the tribute formed only a part of the total burden of payments which the Indians had to make. Each married adult paid one real a year into a community fund to provide for the local pueblo government. There were gifts to the village priest or to the bishop for extraordinary services. A share in the expenses incident to the construction of churches and monastic foundations in the important towns was borne by the Indians, as well as one third of the cost of building the cathedral of Merida. Extra-legal demands, especially for food and shelter whenever the encomenderos and their retainers visited the pueblos, were common. And twice during the second half of the sixteenth century the Crown asked for loans or donations.

System of Forced Labor

When the Crown ordered the abolition of the labor phases of the encomienda system, it had to provide some substitute, as the colonists were dependent on the natives for house servants, unskilled laborers for various services, burden bearers and semi-skilled artisans for house building and public works. The Spaniards were free to employ all the labor they needed at the current rate of wages, but the supply of Indians willing to work, even for pay, was often inadequate. Consequently, the Crown found it necessary to authorize a system of forced labor by which quotas of workers were summoned periodically from the Indian pueblos to serve in the mines, on farms, on building operations or in workshops of various kinds. For this labor

they received wages at a fixed rate. This system of forced labor was generally applied in all parts of the Indies.

In Yucatan the demand was chiefly for house servants, building workers and porters. The employment of Indians as porters, or burden bearers, is the most interesting phase of the labor problem in Yucatan prior to 1600, and it illustrates the manner in which the humanitarian principles of legislation so often had to give way before the hard facts of administration.

Informed that the use of Indians as porters in various parts of the Indies had resulted in very serious abuses, the Crown issued orders strictly limiting this form of labor to areas where pack animals were lacking or could not be used—and even in such areas the Indians were not to be forced against their will to perform this kind of service. In Yucatan for twenty years after the conquest there were few roads or pack trails, and the supply of oxen, horses and mules was inadequate. Consequently the employment of Indian porters was universal. The most important demands for this kind of service came after harvest, when the maize that was paid as tribute or purchased for export had to be carried from the villages to Merida and the other Spanish towns. The wages for this form of labor were probably the lowest that were paid; the average load of maize was between fifty and seventy-five pounds; and a day's journey, according to the wage scale, was five leagues. Moreover, the Indians were given no choice in performing this service. Levies were called on order from the provincial governor, and caciques who refused to furnish the necessary number of porters were fined or imprisoned.

In 1563 the alcalde mayor served notice on the encomenderos that within one year they should purchase carts and animals for transportation of the tributes on the new roads being opened up, but this order was never executed. In the 1570's the defender of the Indians brought suit to force the encomenderos to give up the porter system, but after long litigation the matter was left to the discretion of the governor. The encomenderos made use of the obvious argument that the Indians had always been burden bearers, inasmuch as they had never had pack animals. The defender's plea was based (1) on the definite royal order that Indians should not be forced to perform this form of labor against their will, (2) on the alleged abuses of the system, especially the exhausting character of the work, and (3) the inadequate wages.

A Defender of the Indians

That the employment of Indian labor in Yucatan gave rise to numerous abuses and hardships is beyond question, but a large part of the documentary evidence is too circumstantial to be useful. But a brief review of the career of one of the defenders of the Indians who made a real effort to ameliorate labor conditions will indicate how difficult it was to mitigate the abuses which existed.

Francisco Palomino was appointed defender of the Indians in Yucatan in 1569 and served with brief interruptions until 1586. The energy and fearlessness with which he denounced flagrant cases of maltreatment of Indian laborers quickly earned him the enmity of both the governor and the encomenderos. The latter bought up his debts, hoping to bankrupt him, but he was saved by the intervention of Bishop Landa, who loaned him money with which to meet his obligations. He was removed from office by the governor, but was later reinstated by the Audiencia of Mexico. The governor then made public a memorial addressed to the Crown by Palomino in which he accused the encomenderos of various acts of violence and other abuses against the Indians. The encomenderos brought suit on the charge of slander, and Palomino was

forced to make a personal appeal to the Council of the Indies. The king sent him back to Yucatan to continue his labors, but a few years later he was once more removed from office by the governor, and he died while preparing to make one more journey to Spain to seek vindication. Palomino's long but futile campaign commands our sympathy. Unfortunately, he was a voice crying in the wilderness.

Effect of Christian Religion

The introduction of the Christian religion had just as profound effects on the traditional folk culture as the loss of political independence or the imposition of a system of tribute and labor which made the Maya "hewers of wood and drawers of water" for an alien race. It may have required an even greater degree of adjustment for the Maya to accept a new religious faith than to change political rulers.

The temple worship with its traditional ritual was the most highly formalized part of native religion, and the priestly class, as custodians of that knowledge which enabled them to perform the traditional ceremonies at proper intervals and to mediate between the people and the powers of the invisible world, exercised tremendous influence. But every individual, as he followed the daily round of life, planted his milpa, shared in the communal hunt, tended his bees and faced the crises of life, performed a series of acts that were religious or had implications of a religious character. The old tradition provided him with explanations for the phenomena of nature and the means for propitiating supernatural powers. It gave him standards of conduct and answers to the riddle of life.

And now, suddenly, he was informed that these traditional modes of life were wrong. A new God, new ceremonial practices, a new priesthood and new standards of conduct were offered to him—indeed forced upon him. That the new faith brought to the Maya definite benefits is too self-evident to require discussion. But it also had powerful repercussions on Maya life and folk achievement which we are likely to forget.

The Missionary Program

The missionary program had two phases—the positive and the negative. The positive phase included the teaching of a few essential elements of Christian faith and ceremonial; the negative consisted of measures to destroy the old cult, and, in so far as possible, the confidence of the Indians in the efficacy of the old ways.

The diocesan instructions of the first bishop, Fray Francisco de Toral, set forth the essential aims of the mission program in this early period. The Indians were to be baptized as rapidly as possible after receiving some instruction in the new faith. This instruction should emphasize such fundamental concepts as the belief in one God, the nature of the Trinity, the Incarnation and the Virgin Birth. A few prayers were to be taught, such as the Pater Noster and the Ave Maria, and these were to be followed by the Creed. Reverence for the Cross, respect for the clergy and punctual attendance at mass were stressed. Persons in danger of death were to be given general confession and called upon to renounce the devil and the idols by which he deceived men. Especial care was to be exercised in teaching the true character of the sacrament of marriage, and the degrees of carnal and spiritual relationship within which marriage was prohibited.

But even these few essentials involved a drastic change in the religious life of the natives, and the Spanish authorities, secular as well as ecclesiastical, realized that only by utmost vigilance could this minimum program succeed. The greatest threat to the new ways was the influence of the native priests and caciques and the continued practice of pagan

ritual. Consequently the negative phase of the missionary program was hardly less important than the positive. The celebration of Indian festivals at night was expressly forbidden, those performed during the day were carefully supervised and the wearing of old ceremonial costumes prohibited. Secret gatherings in the houses of caciques were not permitted, lest these meetings be made a means of perpetuating the knowledge of the old ways and the influence of the native leaders. The custom of employing a casamentero, or native marriage maker, was forbidden, as a means of ensuring the free character of Christian marriage. Body painting and the use of ear-plugs and nose ornaments were prohibited.

Enforcement of mission discipline required constant vigilance and effective disciplinary measures. The form often employed for serious offenses was corporal punishment. Persistent offenders were frequently banished from the pueblos, and from time to time the clergy, in conjunction with civil authority, exacted even more stringent punishment, especially for cases involving practice of the forms of idolatry.

Disciplinary Measures

The most celebrated case occurred in 1562. Informed that the Indians in the southern part of the province were performing idolatrous practices, Fray Diego de Landa, provincial of the Franciscans, with the consent and aid of the civil authorities, made a thorough investigation. Torture was used to obtain evidence, and several Indians confessed participation in human sacrifice. Later these same Indians repudiated their testimony, asserting that they had made false statements in order to escape the rigors of torture. Sentences of various kinds—fines, whipping, and in some cases a period of personal servitude varying from two to ten years—were imposed on the persons convicted of having taken part in idolatrous practices, but many of these sentences were later commuted to lighter forms of punishment by Bishop Toral. Thousands of idols were gathered and destroyed. In a few cases the bodies of deceased idolaters were exhumed and burned. Several Indians who had been denounced as participants in human sacrifices, of whom the most important was Lorenzo Cocom of Sotuta, committed suicide.

Perhaps the most interesting thing in the entire manuscript record of this famous incident is the clear indication that the persons against whom Landa and the alcalde mayor directed their attack were the caciques, the lesser chieftains and the native school masters. Ten chieftains of Mani were arrested and held in jail in Merida; seventeen from Sotuta; nine from Homun; thirteen each from Yaxcaba and Canchunup; as well as a long list from other pueblos. Altogether more than one hundred were thus publicly punished and humiliated. We should not be too critical of Landa and the alcalde mayor, especially if we realize that the evidence, obtained by torture or the threat of torture, it is true, and later repudiated, seemed to indicate the practice of human sacrifice. They were the agents of a virile, dominant culture which justly regarded such practices as an abomination.

But my point is not to argue the superior quality of European civilization and the Christian faith—they do not need an advocate—but to direct attention to the fact that by discrediting the former political and religious officers the authorities were attacking the intellectual leaders of the race. These men were the custodians of the complicated chronology and hieroglyphic writing which were such essential elements of the whole body of folk tradition. By holding them up to public humiliation, by a definite process of eliminating them from posi-

tions of influence and authority, by banishing them from their traditional haunts, by forcing them to practice their profession in secret, if at all, the civil and ecclesiastical authorities were striking a serious blow at some of the greatest achievements of the race.

As usually happens, however, the leaders of the conquering race, having demonstrated their superiority, turned antiquarians and preserved for us some knowledge of the traditional Maya learning. And of these antiquarians, Landa was the greatest!

Old Faith Not Wholly Destroyed

But despite the stern measures for the punishment of idolatry taken in 1562 and on other occasions later in the century, a considerable amount of folk religion survived as part of the everyday life of the people. What was lost was the temple ritual and the learning of the caciques and priests. The net result was to impose a veneer of Christian practice without wholly destroying the old faith.

The reasons for the failure completely to substitute the new faith for the old are numerous. During the first century after the conquest there was a lack of clergy. A single friar or secular priest sometimes administered a parish of several thousand. Moreover, the language problem was never surmounted. The village schools did not succeed in teaching Spanish to more than a small proportion of the Maya. Many of the clergy, it is true, learned the native language, but due to the fact that a large number of priests, especially in the Franciscan Order, were recruited in Spain, it may be doubted whether more than 60 per cent. of the clergy were proficient in Maya at any given time. Frequent petitions were made asking the Crown to order preference for clergy born in Yucatan in appointments to curacies, but during the first two centuries these petitions had little effect. Rivalry between the secular and regular clergy also reduced the effectiveness of the small and inadequately trained group available for the missions. Moreover, the lack of cooperation on the part of the civil authorities and the eager desire of officials and colonists alike to exploit Indian labor hindered the progress of the missionary program from the beginning. Finally, we must not forget that there was always a means of escape for the Indian who refused to accept the new régime. Hundreds escaped into the central part of Yucatan, where they could practice the old religion without interference from the Spanish clergy or civil authorities. And these settlements in the bush became in turn centers from which the folk religion could be "bootlegged" back into the conquered area.

The fate of the Maya was essentially the same as that of other aboriginal populations which have been brought into contact with a more advanced civilization. The influence of the intellectual leaders was gradually lessened. But everyday elements of culture, the language, the simple agricultural economy and a body of superstition that was preserved under the surface of a new cult remained, due largely to the inertia and powers of resistance of the masses.

SCIENTIFIC ADVANCE, MEDIEVALISM AND MODERN BUSINESS

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In the fourteenth century a series of disastrous occurrences gave tremendous impetus to forces which had long been accumulating in Europe and which eventually broke the vast power of the feudal hierarchy and the absolute authority of the Church. The depletion of the soil with extensive crop failures and great famine of 1315–16; the Black Death of 1348–49, which wrought incredible havoc and reduced the population 30 per cent. to 50 per cent.; the English Statutes of Labourers, beginning with 1349 and reenacted for a century and a half, which aimed to stem the growing tide of higher prices and wages; the abortive Peasant's Revolt of 1381; the Enclosures of England and the extensive turning of farm lands into sheep walks to supply a rapidly-growing foreign trade—these and similar occurrences marked the passing of serfdom and villeinage, the eclipse of small-town life (where craftsman rose from apprentice and journeyman to independent master), the ascent of a relatively few powerful merchant adventurers and industrial barons to positions of widespread economic control and the beginnings of the modern business system. In this transition feudal lord, emperor, king, pope and city merchant-industrialist struggled to retain or to gain supremacy.

Technological and Scientific Advance

As a result of these struggles for power, the fate of medieval Europe might well have been that of the ancient Greek city-states or of the Roman Empire had it not been for important technological and scientific developments which occurred in Europe during the same general period.

First, there was the thorough-going utilization by Europeans of three devices which in cruder form had been known for a long time, namely, the mariner's compass, gunpowder and the printing press. Improvements in these devices now opened up for Europe hitherto unheard-of opportunities for geographical discovery, colonization and further plunder; sealed the fate of the knight-errant with all his spectacular paraphernalia; and rendered the stored-up knowledge of the privileged few ultimately accessible to the humblest peasant. The effect of such advances upon the rise and spread of modern nationalism, imperialism, democracy and popular education, and the repercussions of these upon the economic structure and the extension of the modern business economy can hardly be overestimated.

By the fifteenth and sixteenth centuries, the first effects of these developments had already helped here and there to resolve the afore-mentioned struggles in favor of king, city and nation, and the scene of conflict was shifting to the international arena. The tremendous expansion of trade and industry following the Crusades of the earlier centuries and the later Portuguese and other voyages of discovery threw off medieval restrictions upon price movements and money-lending; the Protestant Reformation merely accelerated these developments; and the influx into Europe of plundered silver and gold from the New World, in addition to an increase of indigenous mining of precious metals, still further disrupted existing systems of prices. A veritable

commercial revolution was the result. Developments in the succeeding centuries followed in natural order: the rise of one monarchial nation after another to world power (Spain, Holland, France, Sweden, Russia, Prussia, England); a scramble for possessions overseas, in North America, India, Africa and elsewhere; the development in the United States and France of modern democracy. These political and economic changes were in the main the natural consequences of the technical advances mentioned.

Second, with the eighteenth century, scientific progress brought even more revolutionary changes in the economic realm, as an outgrowth, to begin with, of Newtonian physics and, later, as chemical discoveries added to man's increasing control over natural forces. The so-called industrial revolution, which followed the commercial revolution, was in essence a mechanical revolution. Machinery driven by artificial power, rapid transportation by railroad and steamship, world communications by ocean cable and electric telegraph, greatly increased use of structural materials and gigantic building with iron and steel, steam power followed swiftly by electric power and then by gasoline combustion and by the mass production of machines and appliances previously undreamed-of—these were the significant elements in the industrial advance. Nor were the political and social effects of the mechanical revolution any less important—the rise in living standards, the abolition of chattel slavery, the spread of popular education and the extension of democratic controls being among them. It was in the main scientific discovery and technological applications thereof which made the modern world a more promising dwelling-place for people in the mass than were even ancient Greece and Rome for a relatively few citizens at the height of the glory and splendor of those nations.

Further Developments of the Market and Price Systems: The Modern Business Economy

Further effects of revolutionary technological and scientific advance upon the institution of the market and price system have been mainly in the direction of a greater elaboration and complexity on the one hand and of a marked instability on the other, bearing in mind that the chief purpose of the institution continued to be served, namely, the yielding of feudal tribute, in so far as the medieval period lingered on, and the yielding of interest, dividends and profits, in so far as the modern business economy took more definite form.

In the various struggles between church and state, feudal lord and king, landed aristocracy and town merchant and industrialist, the chief economic issue continued to be one of what dominant class was to secure the greatest share of the medieval "spoils" or "surplus." In this conflict between dominant classes, the social and economic status of the people was little enhanced, and in some respects it continued to grow worse. The people still lacked political power; and the laws and judicial procedure covering property and status formulated by the feudal overlords—together with the ecclesiastical and dialectical sanctions supplied by the medieval Church—continued to offer innumerable stumbling-blocks to an improvement in general living conditions. Furthermore, until more recent times, the efforts of the people had to be concentrated upon the more immediate problem of securing greater personal and political freedom. Only as that primary problem came to be solved in some measure, could the people hope for any real success in attacking the problem of improving their economic status.

The "price revolution" of the sixteenth and seventeenth centuries, due

mainly to the influx of silver and gold from the New World (from Mexico, Peru and Brazil), produced marked effects upon estate holdings, colonization, export trade, ship-building and money lending. In the seventeenth century the London goldsmiths developed their operations as deposit bankers, lent money at interest, began to pay interest on deposits and finally issued "promises to pay" or goldsmiths' notes. The Bank of England was established in 1694.

At the same time, English wholesale and retail trade and foreign commerce became greatly augmented, the picturesque fair declined, large-scale business enterprises multiplied, insurance and hedging took on sizable proportions, the collapse of the Mississippi and South Sea undertakings in 1720 marked the beginnings of even greater speculative ventures, severe business crises followed with every passing decade during the second half of the century, and the London Stock Exchange came into being in 1773.

A new monied class now began to vie with industrialist and merchant for a share of the "surplus" through investment and banking operations, and the frenzied finance of modern times with its kaleidoscopic crop of millionaires and multi-millionaires was ushered in. Likewise, attention became focused here and there upon problems long neglected by the classical economist.

The commercial, trading and financial transformations just described paved the way for the establishment of the modern business economy, the most significant economic development of the period under review. The essential elements of any business system are a sufficient political security for the regular enforcement of trade contracts, some recognized medium of exchange, the accumulation of surplus stocks of goods and the conduct of enterprises for the primary purpose of profit making. Neither barter nor a household or manorial economy involves all these elements.

Various ancient states had developed business economies—maritime and merchandizing trade, money and banking facilities and profit-making ventures having been elaborated to a considerable degree. But business practices then, and on a reduced scale throughout the medieval period, were confined almost entirely to commerce and finance. Industry as such was primarily a household affair, and agriculture was carried on chiefly by slave or serf labor with non-business factors and processes predominating.

What distinguishes the modern business economy from earlier forms is its extension to industry and agriculture, particularly to the mass production of fabricated commodities with the use of highly developed machine technique, made possible by the scientific advances outlined.

If, toward the end of the eighteenth century, England led the way, as she did, in the extension of business practices to industry, it was because of the aforementioned wide expansion of her trade, the proficiency of her merchant-adventurers in the arts of finance and money-making, the development of her textile industry on a machine basis, ready access to the raw materials necessary for large-scale industrial use, and because the enclosures of her agricultural lands drove large numbers of dispossessed peasants to the cities, where they could be readily utilized as factory laborers. The relative political security of England and the liberality of her laws of contract were also important factors in this development.

On the Continent, conditions were not as favorable. The Napoleonic and other wars of conquest and the continuance of medieval restrictions held back industrialization and the expansion of business there. Furthermore, in France the

workers remained relatively secure in their medieval agricultural pursuits, in Germany and Italy the struggles between petty feudal lords and ecclesiastical powers continued to render difficult any unified national development, and other countries remained even more backward.

To colonial America, European settlers had brought the economic customs of the home countries, including old-world ideas of property, status and the market and price system. For a time frontier life in a new land caused a reversion to barter and economic activity for immediate use rather than for profit; but by the end of the nineteenth century, the frontier in the United States had virtually disappeared, the modern business economy had been quite generally established, and American industry and trade fashioned upon European precedents had assumed a place of world leadership. In agriculture, financial organization and investment control, however, America still lagged behind England.

Changes in Economic Thought and Policy

While vast scientific and technological changes were in process and as a result industrial and political units were growing enormously more complex and the modern business system was becoming more or less universal in scope, the world of economic thought and policy remained curiously stagnant, or, rather, the feudal structure of legalistic, judicial and ecclesiastical controls and their dialectical rationalization continued with little change so far as the main stream of economic thought and action was concerned. For the most part during the transition period, the process of rationalizing and apologizing for things-as-they-are went on unabated. The subtle medieval dialectic, with its apologetics for the *status quo*, could hardly be improved upon, and so it survived with merely a change in emphasis and direction as to what form of dominant tribute-taking was to be regarded as "proper" or "right."

Modern Mercantilism

With the triumph of monarchy and nationalism in the sixteenth, seventeenth and eighteenth centuries, a reawakened doctrine of mercantilism succeeded the doctrine of the "just price," to the rationalizing tenets of which it added little beyond the revival of certain Roman and other ancient trading dogmas. For the rest, the medieval tribute-rendering structure continued to be left unquestioned, except that now most of the "surplus" went to king, merchant and industrialist.

Though English, French and German definitions of renascent mercantilism differ somewhat in outlining its extent and significance, there is general agreement that it constituted part of the nationalistic policy of growing monarchies in bringing territorial unity out of feudalism and in enhancing the wealth and commercial power of a given state in competition with other states. Modern mercantilism sought primarily to make the rising nation as such powerful and prosperous, toward which end monarchical regulation of economic affairs was extended to the most humdrum of activities. In England, unity had been achieved and feudalism was already on the wane by the fourteenth century, but on the Continent, where disruptive feudal influences continued four to five centuries longer, various town monoplies and river, highway and other local tolls and exactions obstructed the free movement of trade and the extension of the business economy.

Besides resulting ultimately in the correction of such internal disharmonies and obstructions through drastic nationalistic decrees, the expansion of modern trade beyond state boundaries brought additional occasions for centralized governmental control. Special trading com-

panies were chartered under severe restrictions (as in Spain, Portugal and France) or under dearly-bought privileges (as in Holland and England). In England, where such restrictions were least in evidence, attempts were nevertheless made (as in the Bubble Act of 1719) to check the growth of the "company" in industrial organization. Crude ideas were also held and carried into effect, in connection with mercantilistic tenets, about the virtue of encouraging exports and hampering imports and about the alleged necessity of collecting a large national stock of precious monetary metals to assure the state's wealth and prosperity, ideas which Adam Smith later severely criticized together with the related conception that wealth can be measured primarily in terms of gold and silver. It can not, however, be said that even to-day we have advanced very far in clarifying these ideas. It seems, in fact, that we have recently taken a new fancy to some of them.

To return to the historical account: During the two or three centuries that modern mercantilism held sway, nations rose and fell in wealth and power. At the same time, merchant adventurers and industrial barons prospered increasingly; and as their wealth and power increased, so did their disregard of onerous mercantilistic restrictions. Also, in a growing number of instances, regimented mercantilistic restraints broke down of their own weight. And finally the physiocrats and Adam Smith cast general doubt upon the virtue of the doctrine itself, by launching the opposing doctrine of laissez-faire, which aimed to prove that nations could become even greater and more prosperous if mercantilism were abandoned and neither the state nor any other coercive body were allowed to interefere with what was being redefined as a "natural order" of economic harmonies, automatically regulated by the spontaneous actions of individuals in their own interest.

Laissez-Faire

The idea of laissez-faire is encountered fairly early among Italian economists, but it apparently first took firm hold in the eighteenth century in France among the merchants (as Gournay and Legendre) and among the physiocrats in their fight against mercantilistic restrictions. In England, Adam Smith promulgated it at the end of that century, and it became current there with John Stuart Mill in the middle of the nineteenth century.

Besides representing a protest against mercantilistic restrictions in general, laissez-faire was, at the beginning, also a protest against any taxation of industry by the state, both of which were natural enough protests at the time, since governmental restrictions and taxation alike continued to reflect efforts by king and feudal baron to maintain the medieval tribute-rendering mechanism intact. In the end, for one reason or another, laissez-faire swept the realms of theory and policy alike and, at least so far as the older form of modern mercantilism was concerned, occasioned the abandonment of that doctrine. The acceptance of laissez-faire as a national policy accelerated the spread of the modern business economy.

Theoretically, certain of the assumptions of laissez-faire are highly important, since they allegedly take into account the welfare of every citizen and not simply that of a powerful few. In the main, these assumptions are: (1) that every individual naturally and with thorough-going rationality pursues his own interests; (2) that he can best follow his bent if left to himself, unhampered by governmental restriction or private organization; (3) that in freely pursuing his own interests, each individual, whether employer or workman, will amass the maximum of wealth for himself; and (4) since national wealth is merely the sum of individual fortunes, that the nation's wealth and happiness

must under laissez-faire reach its maximum. As part of this doctrine, Adam Smith consistently argued against the chartering of joint stock companies, on the ground that, in such organized business concerns, collective management is substituted for individual enterprise. Laissez-faire was, therefore, among other things originally directed against tariffs, diversions of trade or of precious metals from the channels of their "natural flow," corporate business organization and monopolies of every variety.

Left out of account, however, by Adam Smith and his followers, were certain practical conditions and developments which in large part nullified their theoretical assumptions. These nullifying factors were in part: (1) the medieval tribute-rendering mechanism was still intact in its legal, judicial and practical aspects, sharply differentiating the hereditary property-holding rights and privileges of the few from the obligations and social submergence of the many, making it impossible for the common people to pursue their own interests unhampered and enabling the merchants and industrialists to continue to secure increasing advantages for themselves. (2) These feudal restrictions and traditions made it extremely simple for those who had money and property to gain more money and property, while rendering it difficult for others to secure even a foothold. (3) The assumption of a predominance of rationality in economic behavior was not in accord with the facts. (4) The supposition that a removal of mercantilistic restrictions would leave competition free, either as between the ruling classes and the masses or as between competing merchants and industrialists, was thus unwarranted, both because of the continued existence of the feudalistic mechanism of political and economic controls and because of the lack of any regulation to prevent merchants and industrialists from getting together and restricting competition in their own interests.

It did not take long for some of the shortcomings of laissez-faire to become manifest: Women and minors were treated scandalously in the factories, so that it had to be conceded that probably they did not know "their own interests"; factory conditions in general brought new industrial uncertainties to wage-earners until their lot became notoriously bad; monopolies developed rampant, despite the vaunted benefits alleged to flow from "free enterprise" in preserving competition. These difficulties brought new legislative restrictions, though of a somewhat different character from the older mercantilistic decrees.

But despite all this, the unreal assumptions of laissez-faire accorded so well with the aims of growing business and with the inchoate structure of economic thought previously devised by ecclesiastical and scholastic dialectic in connection with the doctrine of the "just price," that the practical difficulties (where recognized) came to be looked upon by business men and economists alike as mere aberrations or exceptions to the alleged beneficent "laws of nature." Nor did this further refinement of scholastic dialectic stop here. With the launching of Benthamism and utilitarianism, other powerful sanctions were added to the "natural order of economic harmonies." Now not only was man, in seeking his own interests, assumed to arrive at the maximum of material gain for himself and for society, but he was thus also assumed to arrive at the greatest possible pleasure for himself and for every one.

This reasoning was still largely on the side of productive effort (of the maximum supply of goods and pleasures), the technical economic arguments being directed to the idea of "cost." Then came William Stanley Jevons in England and the Austrians on the Continent, who emphasized "utility" to the consumer or the pleasures involved in demand. Henceforth, the classical justification via laissez-faire departed somewhat from the

Smith-Ricardian "cost" pattern for the new pattern of "utility," and the condemnation of governmental and monopolistic restrictions was shifted to the contention that these do not allow "free play" to consumer demand. The "natural-order of economic harmonies" was still retained, but in measuring "pleasure" and thus "value," the emphasis was changed from a "natural pursuit of one's own interest" to the prices consumers are "willing" or "offer" or are "prepared" to pay. Later came the final refinements of eclecticism, demand and supply being viewed as "two sides of the same shield" or as the "two blades of the price-setting shears," and the classical structure was complete. Bulwarked by Benthamism, marginalism, Austrianism and eclecticism, its general scheme of dialectic seemed to grow ever more plausible.

To what an extent this whole structure of classical and neo-classical economic thought, despite its surface plausibility, is interpenetrated with unwarranted assumption and false reasoning, the present writer has already had occasion to examine at length elsewhere. Here we are chiefly concerned to call to mind the major respects in which, with the abandonment of mercantilism, changing economic conditions and the establishment of modern business as an outgrowth of scientific advance did not conform to the "natural" course of events predicted by laissez-faire.

That the latter failed in its theorizing to take into account the conditioning rôle of medieval economic institutions has already been pointed out. Its further failures in prediction and in even surface consistency may in part be summarized as follows: (1) Despite the withdrawal of governmental assistance, corporate business organization underwent no natural decline; on the contrary, its spontaneous growth is one of the outstanding features of modern industry and business; hence the arguments of laissez-faire, based upon an inevitable victory for individual initiative and enterprise (if left to themselves), lose much of their significance. (2) Monopolies and combines have already been mentioned; they grew apace as corporate enterprise grew, until we witness the incongruous spectacle of governments issuing regulations to break them up, in the name of a laissez-faire one of whose primary protests was against state interference. (3) Similarly, we observe state after state passing factory acts to remove some of the "unhappy" conditions caused by a laissez-faire which insisted that happiness could be brought about by "natural laws" alone. (4) Again, as large-scale industrialism and business developed, salaried managers increasingly took over the actual conduct of business and the profit incentive shifted to the investment field, so that "individual enterprise" now centered for the most part upon the holding of stocks by absentee owners, which is quite contrary to what laissez-faire contemplated. (5) Free traders, in endeavoring to remain faithful to the precepts of laissez-faire, overlooked the fact that through formal and informal combines and monopolies large-scale producers have been increasingly able to exercise control over prices, while the unorganized consumer (who under "utility" economics should have complete freedom of choice) became less and less able to do anything but accept the price-ranges thus fixed. (6) Modern production has, in fact, become more and more regulated, both by governmental enactment and by internal controls. American anti-trust legislation and European cartels were already established before the world war; and since that time, not only has there been a further increase in industrial combination and restrictive legislation, but projects of national planning which deliberately link the state with economics have become wide-spread, whether we look to-day at Russia, Italy, Germany, Mexico or the United States.

In the realm of production, the tenets of laissez-faire seem nowhere to have worked out as predicted. (7) As for consumption, the disadvantageous competitive position of the unorganized consumer is now well known. In addition, after Austrianism rose to favor, it was soon pointed out that, where there is great inequality of income, price-offers as such can not in any comparable sense measure underlying "pleasures" or "utilities." A more equitable distribution of income and wealth would doubtless be conducive to greater general satisfaction, and this might well be brought about by state control and graduated income taxation, thus again contravening one of the basic "non-interference" tenets of laissez-faire in the interests of achieving another one of its tenets, the "maximum of satisfactions" or the "greatest happiness of the greatest number." (8) Also, while the economic power of the consumer has been increasingly weakened by large-scale corporate control and absentee stockholdings, his political power has become increasingly greater with the growth of democracy, under which he is progressively exercising direct economic interference in the interests of public welfare, again in contravention of the "natural harmonic" assumptions of laissez-faire. Here conscious democratic control is definitely replacing a let-alone governmental policy. (9) Finally, with respect to the alleged comprehensiveness of the "natural order of economic harmonies," a most important group of modern economic phenomena is left entirely out of account by laissez-faire economists, namely, that complex of events known as business cycles.

Considering by and large the developments in economic thought and policy just reviewed, we find that the chief beneficiaries of the change from older medieval doctrine to mercantilism and laissez-faire, brought on by modern scientific advance, were the merchants and the industrialists, although the monarchs and the lords continued to secure some of the tribute or surplus by virtue of persisting privileges, customs and land holdings, and although the people themselves were also supposed to benefit somewhat by the change to laissez-faire, especially by the lower prices which to some extent did result. In the main, laissez-faire appears simply to have added another sanction to the already-existing scholastic apologetics, the sanction of a supposed mechanically-operating natural law of "competition" or of "economic harmonies" under an allegedly "free enterprise," which, along with the assumptions of objective value, natural justice and a divine economic order, established by the earlier medieval rationalization of things-as-they-are, merely served to give further credence to the classical structure of thought. This rationalization, at the same time, continued to hold the wage-earners to their economic status, at least until they substituted direct political action for the wishful thinking of the upper classes. If the people benefited at all under the change to laissez-faire, it was chiefly because of scientific and technological advance coupled with new governmental enactments which they were able to secure in their own interests, hardly because of the let-alone laissez-faire policy in its practical workings, although theoretically it sounded promising enough, certainly much more "equitable" in its fundamental implications than the *status quo* doctrine of the "just price" or the imperialistic decrees of mercantilism. In its practical workings, the doctrine of laissez-faire seems chiefly to have enabled merchants and industrialists to consolidate their control over a tribute-rendering economic structure, in the wake of revolutionary changes in industry brought on by technological and scientific advance, as medievalism gave way to modern business.

THE PSYCHOLOGICAL APPROACH TO THE TRAFFIC PROBLEM

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THIRTY-SEVEN thousand persons were killed on the highways of the United States last year. In the fifteen years preceding 1935 more people were killed by automobiles than have been killed in all the wars of the Republic.

The problem is very definitely one belonging to psychology, because automobiles, properly handled, are fairly safe machines. In the various statistics that have been gathered about accidents, car failure is found to play a very minor rôle, and, if the accident is due to some mechanical defect in the vehicle, that defect is often contributed to by the indifference of the driver. For instance, most of the statistics concerning car failure as an accident cause indicate that the brakes were faulty or that a tire has blown out. Usually nowadays when a tire does blow out it is an old one which perhaps has been purchased second-hand after having been repaired so frequently that every point is a weak spot.

Whether a highway is good or bad does not determine whether there will be accidents upon it if we leave the driver's attitude and mentality out of the picture. People can drive over highways which are poorly paved, which are deeply rutted and which in other ways show lack of engineering improvements with the same relative safety that they can over a smooth road if the driver is cautious and has the proper psychological reactions.

The superficial aspects of the psychology of the driver have been known for years. In a study made by Dr. Simonin,[1] of the University of Strasbourg, in 1931, the bibliography lists references as far back as 1907, for in the bulletin of the Society of Ophthalmology of Paris of that year, Roche asked the question whether it was necessary to determine the safe minimum visual acuity of automobile drivers.

Since then much thought has been given by European observers to the medical and psychological problems arising from the operation of a motor car. In the first decade of the present century the authorities of Berlin, Germany, were demanding physical examinations, including a check of the eyes, and licenses were granted by them on condition that, among other things, the glasses a driver wore should correspond with those that the doctor had determined would result in adequate visual acuity. Naturally, in the years that followed, the ideas of scientific people concerning the physical and mental requirements on the part of drivers have changed. Builders of automobiles have developed their machines so that specific weaknesses on the part of an occasional crippled or otherwise handicapped driver can be properly compensated. The special motor cars which our President drives on his Warm Springs and Hyde Park farms are examples of this, and he is a classical example of the fact that a person with a physical handicap may be at least a reasonably good driver.

In 1928 a very far-seeing judge of the Recorder's Court in Detroit requested that a special study be made of one hundred traffic offenders who had been brought into that court for violations of the traffic ordinances and laws. This was probably the first forward step taken in America to look into the problem of why

[1] Dr. Camille Simonin, "The Automobile Homicide." Paris, 1931.

certain drivers have accidents, why some of them get arrested, and what part the driver's defects played in the serious traffic situation of to-day. A number of findings were tabulated and the report made by the Psychopathic Clinic at that time, written under the direction of Dr. Theophile Raphael, revealed important findings, one of which was a preponderance of feeblemindedness. This immediately gave rise to agitation that the feebleminded should be removed from the highways in spite of the fact that a number of other observers have found cases of extremely bright people, college professors, for instance, whose records on the highway and whose mechanical ability to manipulate a car were inferior to those individuals with borderline intelligence, making them more accident-prone.

Although complicated psychotechnical apparatus was installed in Europe for the measurement of aptitudes of locomotive engineers and bus drivers, the matter was not much stressed in this country until the National Research Council in 1927 granted money to Drs. Albert P. Weiss and Alvhh R. Lauer,[2] who at that time were at the Ohio State University, to make a study of the "Psychological Principles in Automotive Driving." Weiss and Lauer carefully studied what work had been done on the subject previously and came to the conclusion that some of the past work by Americans on the competence of street-car motormen might be of some significance in directing their research, and they made an extensive study of the psychological abilities manifested or not manifested by operators who were good or who were bad drivers. Contrary to the teaching of some laymen, they found that a very small group of drivers could be considered definitely "accident prone," that is, to have a large number of accidents, and they attempted to develop criteria for automobile drivers. Behind the establishment of such a criterion is always the question of what is "good" or "bad" driving. Nobody really seems to know to-day, even though it is seven years since Weiss and Lauer reported what they found. The fact that there is no central bureau for guiding and supervising psychological research has complicated the matter and given rise to various conflicting points of view.

At the present time there are three bureaus in the United States which are doing research work on the competence of drivers. Each has a different approach. Lauer has continued to work on the psychological requirements for safe driving, but recently he has stressed visual phenomena and, of course, this is only part of the answer to the problem. He, himself, will undoubtedly admit this.

DeSilva, at Harvard, in the Bureau for Street Traffic Research, has modified a number of Lauer's tests with the idea in mind of making some simple objective apparatus which can be manipulated by the layman. This approach, to my mind, is fraught with dangerous possibilities.

The third center for this work is the Recorder's Court Psychopathic Clinic (Traffic Unit), which has an entirely different point of view. Lauer and DeSilva are doing research work, qua research. The Recorder's Court Clinic is faced with the concrete problem of deciding whether or not a specific driver is safe to be behind the wheel of a car, and if not whether anything can be done to make him a safe driver or whether he is a hopeless case who must be removed from the highway. To study him, as Canty has reported,[3] he is given a physical examination to see if he has a physical defect, whether he is crippled or weak so he can not operate

[2] Albert P. Weiss and Alvhh R. Lauer, "The Psychological Principles of Automobile Driving." Ohio State University Studies. No. 11, 1930.

[3] Alan Canty, *Jour. Applied Psychology,* Vol. XX, No. 4, August, 1936; and *Public Safety Magazine,* March, 1937.

a lever properly, whether he has a visual defect that precludes his seeing objects standing still, cars coming toward him or the condition of the road ahead. He also is given a group of examinations which we might call psychophysical tests. These are in keeping with conventional psychology, *i.e.*, they are tests of reaction time and judgment ability of various kinds. The subject is also given a psychiatric examination or, perhaps better, a mental hygiene examination, for the object of this part of the personality investigation, even though it is carried out by a psychiatrist, is not primarily to find out if an individual is suffering from a mental disease, but to disclose less obvious but equally important deviations in his mental processes.

Since the situation is basically simple, it is surprising that the psychological basis of traffic deaths has by no means been solved. One reason rests in the peculiar scientific situation which exists among those doing research on the psychology of drivers. When a medical man does research he usually publishes his findings either in a note or a more extensive article in one of the professional journals, so that, if his colleagues are at all interested in applying his discovery to their work it requires little in the way of effort to obtain copies of the periodicals where his findings appear. The traffic specialists, in the first place, seem to prefer to give their material to newspaper correspondents, and even if they do publish it in scientific journals, their work is found in such obscure periodicals that they are not as a rule easily brought to hand. The frequent use of publications such as the *Journal of the American Optometric Association* and, in England, the *Personal Factor*, are examples of this. There is little interchange of thought between workers in this field, and natural professional rivalry seems to be accentuated in it. One can scarcely blame an honest research man for concealing his work until he has established the principles which he has set out to verify, but after he has obtained results in thousands of cases these results should appear in the literature, but only too often in motoring-psychology they do not.

The consistent use of the psychological examination of offenders now stagnates, and the reasons which I have given above are causes but they are not the only ones. Money which probably would be forthcoming for research in this field from various sources, such as the manufacturers of motor vehicles, highway commissioners and health officers, has been allocated only to a few persons. There is, perhaps, a reason for this, too, in that those who are engaged in the automobile industry have preferred to see as many cars sold as possible and, while they have made concessions to safety, the "personal" element offered a challenge to them, for it might cut down the volume of their sales. On the other hand, I have been told recently by far-seeing executives in automobile plants in this city that they feel that everything that can be done to make for safety will eventually have a sales value. Unfortunately, this point of view is not predominant in the whole industry.

Several hundred cases have now passed through the clinic, and our findings seem to be diametrically opposed in some respects to those which might have been predicted by the public as exemplified by members of "safety committees," police officers and other persons untrained in psychology.

For instance, the layman, when considering the subject of accidents, assumes that if the driver can stop in time he can avoid any kind of an accident. Newspapers and magazines are filled with articles showing how long it takes to stop a motor vehicle going at various speeds, on the assumption that if an individual

reaches an intersection at too rapid a pace, he can not stop in time to avoid a car which might appear from behind a blind corner or might suddenly emerge from some other obscure point. In order to stop in time it appears to the layman that there are only two facts involved: one is how quickly the driver can see a car coming and press on the brake, plus the length of time that it takes the brakes to stop his car after he has pressed on the pedal. To the superficial thinker that would seem to be the end of the problem: if a man's reaction time is slow and a car comes into view he can not press on the brake in time and he will hit the car.

To the psychologically-trained person the braking time with good brakes, of course, is a disregarded factor to be considered by the engineer, and the theory evolves that an individual should drive at a sufficiently slow speed so that the engineering problem of stopping the car will not be of much significance.

But engineers neglect an important problem, namely, how the individual is supposed to judge how fast he is going with regard to the braking power of his car. School children and others are taught by means of pictures and charts that it takes a certain number of feet for any car to stop and that motorists should drive slowly. Yet at the same time they are taught that they can drive faster on the open road than the street and are given no scientific clews as to the determination of what a proper speed is.

As one would more or less suspect from the discoveries of Lauer and DeSilva, reaction time is not of much importance. Usually it is tested by a relatively simple apparatus, a red light similar to the signal tower found in most cities is flashed in front of the subject taking the test. He steps on the brake, and the time transpiring between the flash of the light and the pressing of the lever is measured. It deviates very little unless the man is markedly diseased or paralyzed; even stupid and feebleminded individuals and those with an impoverished nervous system, but who have no acute nervous disease, deviate only a few tenths of a second. This usually means a matter of only twenty or thirty feet, unless the speed is excessive.

More important than the actual ability to respond quickly is the ability to spot the elements of an impending accident long before it is necessary to press on the brake sharply. If a man can stop his car in five hundred feet he should have an idea of what is going on in the road five hundred feet ahead so that if, for instance, he sees the wheels of a car pointing away from the curb, a man's arm projecting from the window, and smoke issuing from the exhaust, the mental pattern should give him a clew that the man is about to turn out from the curb and may come out without much consideration for the oncoming driver. In this way, being able to step on the brake quickly is of little value if the car comes out without warning.

We have found it interesting, however, to measure reaction time in order to look further for some disease. We often find it interesting to add a steering test if the time is lengthened. Those who have had the longest reaction time of the cases seen by the clinic have been people suffering from paresis due to syphilis, paralysis of certain muscles and stupidity almost at the imbecile level.

The person whose judgment of speed and of spatial relations is poor is perhaps more apt to get into trouble, because when he gets into a ticklish spot he may come too close to another object, but narrow areas through which a man has to drive are infrequent and if the man's attitude is such that he will be careful and watch what is happening, he is not

likely to have an accident. Few cases passing through the clinic show marked impairment of ability to judge speed and distance unless they show some other signs of organic illness.

The reason why most people are relatively safe drivers and do not collide with others is a comparatively simple one and has to do only with the fact that motor vehicles going in the same way are restricted to one part of the highway. If a fair rate of speed by all vehicles is maintained the likelihood of collision is small. An accident occurs only when this fact is neglected or when a man turns out of a stream of traffic to go on a part of the highway where it is predicted that cars going in this direction would not be.

The two characteristics of the driver that are most stressed by policemen and others who think that they have the answer to the traffic problem in the matter of examining candidates for licenses are vision and intelligence. In regard to the last, I believe that I have already indicated that intelligence in itself is not a serious factor in the commission of accidents. Naturally, the more stupid a man is, the more likely he is to make a poor judgment in case he gets into an extraordinary situation, but unless someone else complicates the problem, a man with a limited degree of intelligence can keep himself out of trouble by driving slowly and observing every law. The traffic laws are sufficiently simple so that a high-grade feebleminded man can remember them and react to them properly. This is perhaps the reason why we find that many feebleminded truck drivers do not get into trouble over a period of years.

The clinic knows of many such drivers and interprets their ability to drive safely over a period of years as being due to the fact that drivers get out of their way and trucks go so slowly it gives the truck driver time to make a decision and figure a situation out. This he would not be able to do in driving a pleasure car. Occasionally we find a man who has driven a truck for a long time without getting into trouble but who, when driving his own car, is affected by the speed of the car unfavorably because he is habituated to the slower speed of a truck.

In such a case, if the man is feebleminded, this is of importance. One particular example will illustrate this. The man was sent to the clinic because he had failed to stop for a red light and crashed into another car. This man was found to be feebleminded and had had three accidents after he had purchased a pleasure car for his own use. Previous to this time he had for some ten years been driving a street-sweeper without any untoward effect.

Because so many people with poor vision are found by the police, and the newspapers have made note of this fact, much emphasis has been placed upon tests of vision for the driver. In 1931 Simonin pointed out that even at that time there was a marked difference of opinion about the importance of physical defects. As investigations have progressed we have become more doubtful about where to draw the line about vision and a man's ability to drive. In 1931 there was a debate in European scientific circles about whether a one-eyed man should drive. The argument was that he could not see cars coming from behind or sharply from the side of the blind eye. On the face of it, this seemed to be a logical argument, but again safe driving would seem more to depend upon the prediction of impending accidents than upon the emergency reaction. In the clinic we have seen many cases of one-eyed drivers who have had no accidents. Some of them have supplemented the good eye by mirrors which permitted them to have a wider range of vision. Others were merely careful and turned

their heads sharply when crossing intersections.

Naturally on the basis of probability alone, more things could happen which might bring about an accident in such a case than in the case of an individual with normal vision in both eyes. Most intelligent and socially minded persons with but one eye can keep out of trouble. The same is true with individuals who have lost a limb, but have supplemented this lack of body-part by braces or artificial apparatus of some sort. The writer knows of one man who even had artificial arms on both sides who had never had an accident because he was careful. He drove only on country roads, at a slow rate of speed, compensating for his defect by being careful about his driving.

The usual visual tests which we give to school children who show eye weakness would have only a questionable place in tests for driving ability. For a person who can only read what he should see at sixty feet at twenty feet has poor vision from the standpoint of eye comfort, yet has vision sufficiently acute for adequate driving. We even know of a case, whose vision would be considered bad from a standard set up by eye specialists, who could only see at twenty feet what he should be able to see at one hundred feet. This was not of as great importance as the layman might think, for even though he could only see the letters and not make out their shape at twenty feet, a man with such bad vision can see a car almost one-half mile away on the open road. If he is following another car he can see details sufficiently at one hundred yards so that he can predict what the driver is going to do.

Sometimes there is defective ability to estimate the relative positions of distant objects. This is important but occurs seldom even in the accident-prone population. In such cases a lack of balance of the muscles of the eye is revealed, but the man still can drive. His proneness to accident increases remarkably when he has a defect of this sort, but he, too, can often compensate by careful driving and a proper attitude toward driving. He usually requires skilled ophthalmological help.

Color vision is another factor which receives a lot of emphasis from the lay traffic expert, because 4 per cent. of the population are supposed to be blind to red and green. In other words, he supposedly can not distinguish between red and green traffic lights. It is true that 4 per cent. of the population are color blind according to standards used by researchers, but these individuals usually prove their ability to "spot" the colors in the traffic lights. Only in one case out of several hundred did we find a color-blind man who was blind to the traffic lights, and he was feebleminded, which was perhaps the more important factor in his case.

Range of vision is stressed. There are supposedly a number of people driving who had "gun barrel" vision, that is, they could only see a small area in front and were blind at the sides. From a number of tests on the general population and from our observations in the clinic we would predict that one in two or three thousand would have a diminution in vision of that sort. Visual defects of this type are measured by an apparatus called a perimeter, a semicircular device with the eye at the center of the circle. A disk is moved from the outside to the center. While the eye is fixed on the center of the circumference, the individual tells when the disk comes into view from the side. This shows that he has a blind spot, which is most important in causing accidents, but its great significance seems to be that it indicates the need for a physical examination to see whether it is due to neurosis, to syphilitic damage, diabetes, Bright's disease or brain tumor.

The layman becomes very disturbed

over poor hearing on the part of a driver. As a matter of fact the police department in Detroit ordered that no deaf man be granted a license by the License Bureau, yet all of us might just as well be deaf about 40 per cent. of the time. In the winter time we drive with our windows closed and our motor vibrates so we are fortunate if we can hear a horn but a few feet away.

The crux of the matter seems to lie in the measurement of the subject's attitude toward law enforcement and toward the rights of others. If he is anxious to do well, he will keep out of trouble as far as possible; and, if he is not easily excitable, he should be able to compensate for his visual defects and body structure.

I might summarize the results of our findings in the clinic and of our research into the literature by saying that mechanical tests of a driver's ability are of value but are sadly misunderstood, that a complete understanding of the nature and of the make-up of the individual, his attitude as well as his physical structure, are probably of much more value in enabling us to predict accident-proneness, as his ability to react promptly and to make good judgments, measured by machines.

Unfortunately, attitude and emotional stability are the most difficult things to test. Our best answer to the problem is by means of a polygraphic study of reaction time tests to see whether, as the situation of driving and stopping becomes complicated, the man becomes excited, as indicated by changes in his blood pressure and breathing. In testing his attitude, too, an association-test of words, such as police, law, *et al.*, can be given and his reaction to them can be recorded. If his history shows that he has been unstable in various situations or the psychiatric examination shows that he can be steered to anti-social behavior because of a suggestible make-up, these facts are of significance.

The deciding factor as to whether such tests are of value lies not so much in the test itself as in the ability, training and experience of the men who give the tests. The time has not yet come when these tests can be sufficiently standardized so that they can be placed in the hands of the police department or licensing board. In the hands of a layman who can not interpret what blood pressure recording means, these test results would be dangerous, as for example, a man who was not disturbed in traffic, but was disturbed by the laboratory situation, might be unfairly ruled off the road. Hundreds who are not disturbed in the laboratory, but are really unstable, might be permitted to drive.

It has been the policy of the clinic to recommend correction of all deviations found, but if they are extremely serious or complicated by a faulty attitude, the patient has been temporarily or, in some cases, permanently removed from the highways.

A serious criticism is made by police officers, newspaper men and others when psychological techniques are shown to them, namely, that these techniques do not reproduce the actual driving situation. When the man is taking the steering test in the clinic his mind is not reacting the same as it would if he were actually steering a car in traffic. They claim that when the red light flashes before him in the clinic he does not need to react as rapidly, perhaps, as he would on the streets. The proof of the pudding is in the eating thereof, namely, we can say that many can pass road tests who can not pass a laboratory test, that success on an actual test of driving is much more likely to occur in an inferior individual, so that weaknesses are not revealed, but when passing the man through a clinic examination these are shown up. On the street he has the benefit of habit and training which conceal how he would act

in danger, while in the clinic we can test for innate reactions by medical and psychological methods. Probably the only psychological test that would appeal to the layman would be a road test, but the only road test that would be as accurate as a psychological investigation would be one with completely standardized methods, including collisions and other emergency situations. The road test as given by police officers usually does not involve the creation of anything that simulates a situation in which the man would be likely to let himself get into an accident.

I have tried to show the reader the difficult situation that confronts any one who is trying to deal with the psychological aspect of motoring, and I hope this will serve as a warning against jumping at conclusions about what factor does or does not cause an accident. The average traffic "expert" takes a superficial attitude. He talks glibly about color blindness, reaction time and other tests of that sort which, I think I have indicated, are at best only suggestive of some deeply complicated condition if they are found to be abnormal. I would not for the world want the reader to believe that the clinic has found mechanical tests of one's driving ability worthless. This is by no means true, but the clinic does frown on using apparatus to the exclusion of other scientific techniques. The total personality should be considered in the same way that it is in a mental hygiene clinic. No modern child guidance clinic would make a judgment on the intelligence test alone. As a matter of fact one of the efforts being made by such clinics is to lessen the emphasis placed upon so-called I.Q. tests and upon physical deviations, although at the same time admitting that these tests are important. Public officials, newspaper men and others who stir up hysteria about the number of increasing traffic accidents are prone to demand that science go the whole hog or nothing. They are unwilling to wait for carefully standardized and scientific techniques. From our own experience we believe the clinic has at hand a number of these and our experience in dealing with drivers bears us out. A few drivers whose licenses we have suggested revoking and who have been permitted to continue to drive have become involved in trouble within six months' period of time, not always serious, to be sure, but yet, according to the laws of chance, one of these minor accidents might well have resulted in a death.

DOSTOEVSKY'S MASTER-STUDY OF THE "PROTEST"

By Dr. PAUL C. SQUIRES
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"SIBERIA. On the banks of a broad solitary river stands a town, one of the administrative centers of Russia; in the town there is a fortress, in the fortress there is a prison. In the prison the second-class convict Rodion Raskolnikov has been confined for nine months."

Thus opens the epilogue to "Crime and Punishment," that bizarre, powerful work upon whose pages Fyodor Dostoevsky ruthlessly lays bare the soul of a young murderer. As the exiled novelist wrote his brother Michael from Semipalatinsk in 1858, "such a figure frequently emerges in actual life." It is certain that no one before or since has rivalled this profound exploration into the dark abysses of the wrongdoer's mind.

Led out into the Semjonovsky Square of St. Petersburg with the other members of the Petrachevsky conspiracy, the young Dostoevsky was bound to a stake. He expected to live but another minute, when the barbarous mock sentence was commuted to imprisonment. The four years he served at Omsk in Siberia furnished him the psychological laboratory from which emerged the tormented beings of the "House of the Dead" and the dreadful realism of Raskolnikov's clinical portrait.

Just who was Raskolnikov? What lines of hostile forces had converged upon this youth of twenty-three, driving him to murder, then onward to confession and inevitable punishment? Was there a gradual regeneration and resurrection in waiting for him? If so, through what agency?

The whole world knows the story, which has recently been filmed. Yet its lessons are subtle and inexhaustible; the implications thereof steadily grow and multiply with the passing of time. The interpretation given by Dostoevsky anticipates precisely that of contemporary thought. Summed up in one word, the master key to the criminal act is the psychology of "protest."

Why did the young student kill the pawnbroker hag? For the three thousand roubles he expected to find, whereby he might complete his law training and obtain a post to support his widowed mother and sister? This is what he claimed at the trial. As to his confession, he attributed it to heartfelt repentance; he even tried to exaggerate his guilt. But—"all this was almost coarse."

Planning the act, Raskolnikov soliloquizes: "It would be interesting to know what it is men are most afraid of. Taking a new step, uttering a new word is what they fear most." Then: "Am I capable of that? Is that serious? It is not serious at all. It's simply a fantasy to amuse myself; a plaything! Yes, maybe it is a plaything."

So, he can scarcely bring himself to believe in the gross reality with which his criminal imagery is charged. Especially at the instant when the axe crashes into the skull of his victim, everything remains chimerical—as if he were a mere bystander at the hideous scene.

Razumihin remarked that the guilty man can be tracked down by the psychological facts alone. Raskolnikov, suffer-

ing from acute consciousness of economic impotency, had developed the Napoleonic or Jehovah complex wherewith to combat the agonizing feelings of inferiority. During several years there had become increasingly evident in his case a loss of contact with people. He viewed society through the big end of the telescope, and society had shrunk to nothingness.

Withdrawing completely into his psychic carapace, practical ethical action was replaced by abstract contemplation. Said he, "I am thinking." Like Kipling's Bimi the ape, there was "too much Ego in his cosmos."

Then it was that this immature mind, at war with itself, wrote the fatal article advertising its social philosophy; not original, to be sure, but nevertheless giving testimony which would eventually be turned against the writer thereof with devastating effect.

Men, says Raskolnikov, are divided into "ordinary" and "extraordinary." The rule of life for the herd is submission. To the Chosen, however, any crime or transgression of the moral law is permissible.

Napoleon is the captain of the supermen who are strong enough to commit crime. Success is its own justification. Those who with magnificent daring "step across the line" have achieved the supreme goal: the conquest of fear.

Narcissus, son of the river-god Cephisus, fell in love with his own reflection in the water. He alone existed. The narcissistic essence of Raskolnikov's personality is powerfully portrayed in the dream about the brutal killing of the horse, where Mikola (the dreamer himself) shouts, brandishing the bar, "My property!"

His vocabulary had become narrowed down to "I," "my" and "mine." We are reminded of Kurtz in Conrad's "Heart of Darkness," who was forever preoccupied with "'my ivory, my station, my river, my'—everything belonged to him."

A frustrated, inhibited being, inordinately vain and sensitive as a mimosa, Rodion longed for nothing so much as independence. The will to dare expanded into a dangerous fixed idea. He will not confess to inadequacy. One must excel in *something.* If, thinks the unhappy boy, the "perfect crime" beckons as the only hope for bursting the shackles of fear, why, so be it. The great men of history have never been squeamish in the use of violence.

Besides, the pawnbroker harpy has no right to live. Like a vampire, she is sucking the blood of her helpless customers. What is she but a "louse," a "black beetle"? The student (really a projection of Raskolnikov) says to the officer at the inn: "Kill her, take her money and with the help of it devote oneself to the service of humanity and the good of all. What do you think, would not one tiny crime be wiped out by thousands of good deeds? For one life thousands would be saved from corruption and decay. One death, and a hundred lives in exchange—it's simple arithmetic."

This is pure rationalization, however, a flimsy bulwark thrown up to protect the sense of self-esteem. The primal motive comes to utterance under tremendous emotional stress in his full confession to the unfortunate Sonia: "I . . . I wanted to have the daring . . . and I killed her. I only wanted to have the daring. That was the whole cause of it."

Raskolnikov's crime represents his protest against a maddening realization of inadequacy. The act was carried out under the influence of a compulsive and virtually somnambulistic state, with the satisfaction of a psychological—rather than an economic—need as the true objective.

Moreover, rage against himself was insidiously transferred to hatred of his prospective victim; she conveniently crystallized for him in her repellant and avaricious person an unappreciative society. The eternal paradox of Roskolnikov's kind, expressed in Sonia's outburst, "How could you give away your last farthing and yet rob and murder!", now ceases to puzzle us.

In upbraiding Sonia for having destroyed her soul for nothing, Rodion is accusing himself. When imprisoned, wounded pride made him ill: his only sin was to allow his *legal* guilt to be revealed. Of pains of conscience he felt none.

Sonia tells him to go out to the crossroads and there bow down, saying to all men: "I am a murderer." He prostrates himself in the square. A drunken workman jibes: "He's going to Jerusalem, brothers, and saying good-bye to his children and his country. He's bowing down to all the world and kissing the great city of St. Petersburg and its pavement."

"Into the Future lead many paths," wrote Nietzsche. What accident of nature and special circumstances make one man a builder of the social order, another a criminal? Out of what differences in ferment do a Beethoven and a Marquis de Sade arise? Raskolnikov, kneeling in the square of St. Petersburg, personifies that legion of weaklings who project their self-hatred upon society.

Poe concludes his "Man of the Crowd" in this wise: "It will be in vain to follow; for I shall learn no more of him, nor of his deeds. The worst heart of the world is a grosser book than the Hortulis Animae, and perhaps it is but one of the great mercies of God that 'es lässt sich nicht lesen.'"

Just a quarter of a century after the American indited these memorable lines, another tragic figure in distant Siberia, from out the gloom of the prison house, unlocked the Book of the Seven Seals in the protest of Rodion Raskolnikov, whose crime was the manifestation and symbol of psychic impotence.

TYPES OF FOREST CARPETS

By Dr. ARTHUR PAUL JACOT
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NATURE has furnished her woodlands with as great a variety of carpets as may be found in a well-appointed home. Entering the woods we are delighted by such forest floor accessories as a cover of Dutchman's breeches, a mat of dwarf cornel, a runner of hay-scented ferns, a haze of woodland grasses sprinkled with pink moccasin flowers under a copse of lady birches along a sandy ridge, beds of autumn asters. In the swamps are spread a layer of lush cabbages studded by the handsome hellebore, runners of sarsaparilla or ginseng along a flood plain, a fringe of cardinal flowers or jewel weed along a brook.

Beneath this variety of herbaceous covers are mats of soft, deep, hair-cap moss cushions of dense grey-green moss, doilies of procumbent moss spreading over old logs and partly buried stones. Open places expose spongy rugs of reindeer lichens, and on old wood, stumps and boulders a great assortment of lacy, foliose lichens. Then all between is veritable diversity in the layer of leaf litter. The fragrant and springy pine litter, and the dark aisles of the hemlock gorge, with their dense carpet of minute leaves, have been enjoyed by most of us. One treads the northern woods on a mattress of spruce and balsam needles. The broad-leaf cover ripples over the hills in ever changing warp and woof, studded by brilliant little flowers that move about the surface, like the blue-tailed skink, the golden-tailed rove beetle (*Ontholestes*), the Calosoma beetle, with its emeralds and rubies set in black lacquer, a woodland butterfly fanning in a sunlit patch, or the minute vermilion Trombidium mites, the blue saddled springtail and a host of others.

CARPET STRUCTURE

The ordinary carpet of deciduous leaves is not a haphazard agglomeration of leaves but has as definite a structure as that of the fireside rug. After removing the few large dry leaves of the surface which form a Litter layer, one finds a more compact zone or layer of leaves which have a tendency to stick to each other by reason of the water-film held between them. These leaves are soft and flaccid, due chiefly to the action of fungi which have partly reduced their tissues. Fungus action precedes other reducing activities, and it can begin as soon as the leaves have enough cover to maintain a little moisture. Leaves further down in this layer are not only matted together but have the edges variously scalloped and the surface (epidermis) more or less removed in irregular patches, while some are skeletonized, that is, the soft tissue is entirely gone, leaving only the veins as an intricate, lacy network. Although reduction is caused by these various agencies, fungus is the most important and the most conspicuous, wherefore this layer may be known as the *F*ungus or F-layer.

Leaves from the south slopes of the hills of the southern Appalachian mountains show chiefly one type of fungus which forms its fruiting bodies in the spongy layer on the inner face of the lower epidermis. These bodies are globular and black. The process of decay is most easily studied by taking a leaf which shows white blotches in the general brown color of the leaf. If such a leaf, preferably oak, still wet from the woods, is placed top side up under a dissecting microscope with a magnification of forty, the upper epidermis can be pushed or rolled back by starting it at

the fork of two veins with a fine needle. (Fine needles can be made by mounting an entomological minuten-nadeln on a handle by means of sealing wax.) This will expose the palisade tissue, or what is left of it, each batch within its vein islet. These islets are inhabited by certain nematode worms. Some leaves are without them, others have them thinly scattered, while some leaves harbor many. Do they feed on the fungal spores or on the fungal hyphae or on the leaf tissue or on bacteria? Who knows? Other stouter nematodes may be found on the surface of the leaves, where wet.

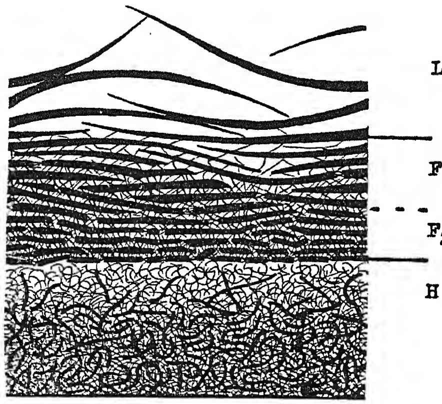
The under sides of dead leaves are quite "dirty." They often bear strands of fungi which hold down feces, both large and small, pieces of cast skins of insects or other arthropods and other minute organic fragments. As such a leaf dries, the photosynthetic tissue contracts and pulls away from the veinlets, thereby skeletonizing the leaf. Another type of reduction is engendered by various chewing arthropods. For instance, leaves may be found in which the lower epidermis has been removed over varying extents. Other leaves may have the lower epidermis, the spongy parenchyma and the palisade tissue removed, leaving the upper epidermis intact. More rarely, certain animals chew holes completely through the leaf. Some millipedes browse about the edges of the leaves. Earthworms, shoots of seedlings or young sprouts push through several leaves together.

Some leaves curl a great deal on drying. Animals take advantage of these and use them as shelters which are consequently found loaded with feces and debris. It is always the upper surface which is rolled in because it is smooth, often glossy and easily sheds water, hence becoming dry more rapidly than the lower surface, which is rough, irregular, ribbed, often with clusters of hairs in the forks of the veins.

Thus, the dead leaves may be reduced (1) by fungal digestion and bacterial digestion, (2) skeletonization (by drying or by animal ingestion) and (3) by fragmentation, chiefly by animals.

Moist leaves of the lower *F*ungus layer harbor a host of animals: fungus eaters, feces eaters, animal eaters, leaf eaters, parasites and transients, for here is plenty of moisture, plenty of shelter and plenty of food. White animals are the most conspicuous, especially the predaceous mites, which go dashing about, and the springtails, which hop about like fleas. Less lively are the immature stages of various saprophytic mites, like those of Ceratoppia, recognizable by two, long, divaricating white bristles on the posterior end of its oval body. They transform or molt on the leaf surface. There are also the young of Eremobelba, grayish with stout white bristles. Eggs—beautifully sculptured, opalescent, knobbed, ribbed, pebbled, chalky, scaly, kinds innumerable, are to be met. But even more numerous and much less conspicuous are the many brown, leaf-colored mites. The larger species occur to the extent of several per leaf, while no one has yet determined the number of minute ones per unit of leaf surface. Why should one? The numbers vary enormously according to the type of carpet and to the degree of moisture. Occasionally, the investigator is startled by having a millipede, centipede, sow-bug, beetle, roach or other animal that recalls dragons and hippos, by contrast with the minute forms, scurry across the leaf or his fingers.

Naturally, such hosts of animal life scatter their excrement about. Strange to relate, most of this animal spoor remains attached to the lower surface of the leaves, and soon becomes webbed down by fungal hyphae. Millipedes are the greatest contributors to the granules found plastered to the leaves—almost always to the surface facing the earth



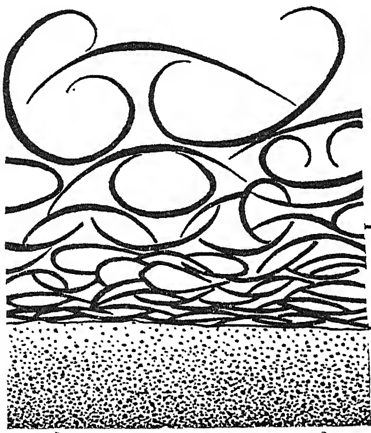
DIAGRAMMATIC CROSS-SECTION OF DUFF CARPET
THE VARIOUS PARTS NOT DRAWN TO SCALE, FAECES OMITTED, LEAF FRAGMENTS SOMEWHAT SEPARATED.

(for leaves have a tendency to turn either side up in falling). The animals have the habit, perhaps sagacity, to push their feces into the forks of the larger leaf veins, or at least against the veins. This may have the indirect effect of hastening vein decay and reduction by such concentration of bacterial and fungal action. Howbeit, the open spaces are left more free for feasting. There are two kinds of millipede excreta. The feces are solid, smooth and dark green. Much more common is what resembles sawdust so agglutinated as to form ribbons or bars. This seems to be regurgitated pellets of partly digested leaves. In the mountains of North Carolina the red-backed millipede (*Polydesmus serratus*) is active all winter long when not frozen, chewing up the leaves. Any warm afternoon after a frosty morning adults will be found sunning themselves on the upper leaves of the *L*itter layer.

By this time the ardent investigator of this sordid life, where all things are something to some one, will have noticed that many of the leaf fragments are more or less "sewn" together by the minute white threads of fungi. It is the fungi, growing through and through and all about these discarded fragments, which bind this organic pabulum together like the woof in the warp. Hence fungi not only digest but amalgamate fragments by the binding action of the hyphae. Each leaf or leaf fragment is a warp thread, while the hyphae are the woof. It is right here that the different types of carpet originate. Some have more or denser woof and some more warp. Let us consider first the carpet in which the woof is more densely developed. Such carpets are known as duff, while those with less fungal hyphae are called mull.

The Duff Carpet

The duff type of carpet is characterized by a third layer, which we call the H (humus) layer. This layer consists principally of completely disintegrated amorphous organic material. It does not include fragments of leaves. It does contain a large quantity of granular material or feces which originated in part in the *F*ungus layer, in part from the overhanging vegetation, in part from earthworms and other soil-inhabiting animals which cast their intestinal wastes above the mineral soil, and in very local part by the feces of animals roving about the forest floor or in the vegetation overhead.



DIAGRAMMATIC CROSS-SECTION OF MULL CARPET
THE VARIOUS PARTS NOT DRAWN TO SCALE, HYPHAE, FAECES AND GRANULES OMITTED, THE BLACK GRANULES IN THE H-LAYER REPRESENT MINERAL PARTICLES, THE WHITE REPRESENTING THE HUMUS.

Normally, the *H*umus layer should form part of the mineral soil, as is the case in the mull carpet, but in the duff carpet it is retained above the mineral soil as a definite layer below the *F*ungus layer. This development was first described by Muller working in Danish forests. He found it wherever the roots of the beech trees, which form extensive forests in middle Europe, spread themselves above the mineral soil. A similar condition obtains in the Appalachians under mountain laurel and rhododendron. These tall ericaceous shrubs form a dense webbing of rootlets above the mineral soil and just under the leaf carpet. As ericaceous plants secrete considerable root acid these rootlets build up a medium which is particularly invidious to earthworms but salubrious to a brown fungus known as Cladosporium. Hence, at once, the most widely known soil mixers are eliminated, and the toughest brown fungi are encouraged. A characteristic of Cladosporium is that its hyphal walls include a great deal of chitin, a hard, brownish, almost indestructible material which makes up a large part of the body wall of beetles. Cladosporium now develops luxuriantly, twining about the network of rootlets of the Ericaceae, filling all the interstices with a much finer meshwork than the rootlets. The combination of a dual system of meshes forms so complete and fine a screen that the particles of humus from the *F*ungus layer are held, clog up the sieve spaces and do not get to the mineral soil. Consequently, the mineral soil lies hard and yellow, like a golden oak parquet floor, under the carpet, which is rendered so tough by the root and Cladosporium meshing that it is difficult to push one's fingers through it and rip it up. Magnificent carpet! Yes, most durable. But that is not what the foresters desire.

The Mull Carpet

In strong contrast is the mull carpet. This may be found under any cover of herbaceous plants, especially annuals, whether spring or autumn (Compositae). The *F*ungus layer is so thin and loosely woven that one has difficulty in finding leaves matted together. So loose is the weaving that the woof is barely perceptible. No brown Cladosporium fungus develops its meshwork. Under this loose and openwork *F*ungus layer lies that fine

black granular material which is so much sought after for garden-flower culture. You can' run your fingers deep into it and find nó yellow mineral soil. It is really the same humus material (feces) that is retained in the *H*umus layer of the duff, but here there is no meshwork of rootlets or of Cladosporium fungus to retain it. Moreover, there are many earthworms of various sizes. Microscopic examination of a sample taken from the black *H*umus layer reveals particles of mineral matter, for the earthworms, ants and other soil mixers have brought mineral soil up into the H-layer, where it has become mixed with the humus, which is nothing more than partly digested vegetation. These mineral granules are not larger than can be ingested by the earthworms, or carried by ants and other soil movers (where the soil has been undisturbed by mammals or the forces of inanimated nature). In mull soil then, the *H*umus layer is so much mixed with the mineral soil that its lower boundary is indefinite, gradually changing from black to the yellow or red of the underlying mineral soil.

Of particular importance to the forester is the fact that in mull soil the tree roots are brought in direct contact with the feces, while in duff soils they are not. These two types of carpet are therefore indicative of two extreme soil conditions: one hard and foodless, the other infiltrated with finely divided animal excrement; one caused by tall ericaceous shrubs, the other brought about by ephemeral herbaceous plants; one "acid," the other less acid.

Extracting the minute animals of these two carpets reveals an astonishing contrast. Not only are the species quite different, but there is a great diversity in numbers and size. Although the total number of species may be the same in each, in the mull carpet the species are large with relatively few individuals, while the duff carpet harbors minute species, each represented by hundreds of individuals. It is therefore evident that the penetrability of the animals of duff is greater—testifying to the closer mesh of the duff. In the open, loose weave of mull, the large species find no obstruction to their movements. The total bulk of animal life of each may therefore be the same.

The White Pine Carpet

Another type of carpet will be found in evergreen needlewoods. Let us take the white pine carpet as an example, say an old-field plantation. The removal of the topmost leaf-clusters reveals a grayish to blackish layer of needles. Such discolored needles already have the five leaves of the bundle matted together by fungal hyphae and "sucked out" so that their walls are collapsed instead of plump. Cutting them in half one finds the spongy parenchyma gone, and only the central stele left. Below these emaciated leaves, but still in the F-layer, the leaf bundles are fragmented and various bundle fragments are matted together by the hyphae, forming a fairly dense and fibrous tissue. The upper and lower halves of the F-layer, therefore, have the same characteristics as the duff carpet, but that layer lies directly on the mineral soil, which is covered by a sprinkling of fine, blackish granules. Here, although reduction is complete, the soil does not seem to receive much benefit. No real H-layer, as found in mull soil, is developed. Herbaceous plants are few and widely scattered. Earthworms are uncommon and small. One must conclude that the white pine carpet is not conducive to good soil fertility. Can it be changed to bring about more mixture between carpet and soil? Here resides the secret of good forest soil and good forest culture. There must be annuals, and there must be root eaters and soil mixers.

Organic Granules

If the leaf carpet of an old-field stand is raised to disclose the underlying mineral soil, the soil surface will be found to be sprinkled with granules of various caliber. But most conspicuous, when present, is a disk two to three inches in diameter made up of granules of apparently uniform size. The center of these lacy doilies is an earthworm burrow, and the granules are the castings of the worm. They vary in hue, according to the color of the mineral soil from which they are largely derived, and average a millimeter in diameter, are slightly longer and have rounded ends. Usually the sides are embellished by concentric or conchoidal black streaks, which are quite prominent when moist. Although the castings of the large meadow and lawn earthworm (*Lumbricus terrestris*) are usually voided to form a nodular clump, the castings of the smaller, woodland worms are seldom found amalgamated, but are strewn over the soil surface or even on the lower, well-decayed leaves. Granules which are deep greenish-black to black are the feces of arthropods. Sometimes the granules will be more or less linked to each other by fungal hyphae to form clots or webs. With time and under certain conditions, granular material accumulates to form a definite *overlayer* of increasing depth. An overlayer of granules two or three inches in depth may lie over the hard mineral soil of an old-field as an entirely distinct unit. As the soil animals work the mineral soil, this sharp distinction becomes more and more obliterated and in time the overlayer becomes the mull horizon of mull soil.

Other types of granular material are also present. Some of them are slender, rodlike and rough. I have seen such under pines, made up of fragments of poorly digested pine needles. As this horizon of granules is a contribution of excreta (either oral or anal, or both) from animals living in the mineral soil as well as from animals feeding in the F-layer or even in the overhanging vegetation, it is not a typical H-layer. It may be conceived of as a no-man's-land or an overlayer. In places, earthworms castings occur in all degrees of disintegration, but when they have lost their characteristic shape they resemble soil granules. With time these organic granules become compacted and amalgamated to form the upper face of the mineral soil.

Let us now look at our carpets in the fourth dimension, considering the time factor. Time is the weaver each autumn spreading out a new layer of warp. Through the year the fungi weave in the hyphal woof and the minute animals eat away at the carpet, reducing it from say two inches to one. What matters it? Next year a new warp will be laid down and more woof woven in. Thus the carpet is repeatedly renewed from upward downward, under our very feet, so gently, so gradually, that we wot not of it nor of its myriad wildlings.

ON THE RATE OF CHEMICAL REACTIONS

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From less than 92 known elements, about a million compounds have been prepared by chemists. More than half of these compounds contain only four elements: carbon, hydrogen, oxygen and nitrogen. How is such a great number of combinations possible?

Certainly there is something strange about this. If we mix two elements, *e.g.*, sodium and chlorine, only three different "compounds" can arise; if we have more sodium than chlorine, practically all the latter will be bound to form rock salt and the remainder of the sodium will be left intact. If we have more chlorine than sodium, chlorine will be left over in addition to the rock salt. There are only three compounds: sodium, rock salt and chlorine. What an enormously different situation we encounter if we consider now the compounds containing only carbon and hydrogen! About ten thousand distinct compounds of these elements are known. The actual number of such compounds is probably only limited by the C and H atoms available to be built into the compounds. Certainly at any particular temperature not all these compounds are stable. At ordinary temperatures, methane is the only hydrocarbon which is stable, in addition to which we can have excess of carbon (graphite or diamond) or hydrogen. No two pure solids of the same composition can be stable over a range of temperature.

Why is it, then, that although a benzene molecule could break up into three acetylene molecules, pure benzene remains unchanged for an indefinite length of time? However, if one adds some suitable compound (a catalyst) the system proceeds very rapidly to equilibrium, the benzene decomposing into acetylene.

It obviously is the slowness of most reactions which allows this almost endless variety of organic substances to exist. This indeed is what makes life possible and prevents our immediate and complete combustion in the oxygen of the air. No wonder that the beginnings of the study of reaction rates are lost in antiquity.

The first measurement of a reaction rate has been made by Wilhelmy in 1850 and the problem of the mechanisms by which chemical reactions proceed has been a center of interest in chemistry ever since. Van't Hoff, in his famous "Étude de dynamique chimique," recognized clearly the *dynamical* nature of chemical equilibria. That is to say, whenever a reaction like

$$2C_2H_6 = CH_4 + C_3H_8$$

comes to equilibrium, this means that the number of ethane molecules being formed in unit time is just balanced by the number of such molecules combining to give methane and propane. The well-known rapid increase of reaction rates with temperature results from the fact that only abnormally violent collisions can lead to reaction and the number of such collisions increases rapidly with temperature. The necessity of high energy concentrations for reactions was pointed out by Arrhenius toward the end of the last century.

At the present time, we believe that the fundamental features of the mechanism of reactions are well understood. This has been possible because of the pioneering work of many brilliant men, only a few of whom we can mention here. W. C. McLewis was the first to calculate the number of violent collisions. To the pioneering work of Marcelin, Polanyi, Bronsted and Herzfeld we owe the gradual development of the notion of the activated state. Rice, Ramsperger and Kassel completed the theory of unimolecular reactions along the lines suggested by Lindemann and Hinshelwood. Lewis and Smith, Daniels and Trautz applied kinetic theory to monomolecular processes and did much in the way of studying systematically many reactions. Later a considerable portion of reactions were found to go faster on the walls, and the understanding of these catalytic processes have been conspicuously advanced by the work of I. Langmuir and that of H. S. Taylor.

The rest of the development is an interesting example of the progress and obstacles and the way they are overcome in the advancement of science. As a matter of fact, we shall see that the calculation of absolute reaction rates is a simple example of the application of statistical mechanics. It is based on the concept that the atoms are moving under the influence of ordinary forces which are also responsible for the chemical valence. The difficulty of physicists in grasping this situation was that they believed on the basis of the older quantum theory that chemical reactions involved rather mysterious quantum jumps. Tolman and Herzfeld derived formulas very similar in principle to those which we shall discuss, on the basis of this theory. Chemists were not bothered by the notion of quantum jumps but were less familiar with the methods of statistical mechanics. As a matter of fact, Rodebush and Rice and Gershinowitz derived formulas which are similar to the ones to be discussed. They, like earlier workers, however, did not make the fullest use of our present knowledge of the nature of forces acting during a chemical reaction.

When the notion of ordinary forces acting between atoms was reestablished by the work of London, it soon became clear how the considerations just mentioned can be formulated on a general basis. This is all that has been done by Polanyi and Pelzer in collaboration with the present writers.

A nice way of representing the motion of the atoms is by a diagram in the "configuration space." Suppose we have three atoms moving with respect to each other in a straight line. The configuration space is two-dimensional then, the X coordinate being the distance of atoms 1 and 2, the Y coordinate the distance between 2 and 3. Every point in this configuration space corresponds to a configuration of the three atoms. The forces between the atoms can be derived from the potential energy for this configuration. If we make a landscape over the configuration space such that the height at any point is equal to the potential energy for this configuration, a ball rolling on this landscape will represent the motion of the three atoms under the influence of the forces between them. The relative position of the atoms will change in reality in such a way that the corresponding point in configuration space always coincides with the position of the ball. If we are interested in a system of more than three atoms or if their motion is not restricted to a line, we must use a configuration space of more dimensions.

Stable chemical compounds correspond to low regions in our landscape. If the ball is in such a low region and has little velocity, it will stay in this region forever. There may be several regions of comparatively low energy, corresponding to several apparently stable groups of molecules. *A reaction will then consist*

in the passing over of our ball from one low region to another.

For such a passage, it needs, first of all, enough energy. The average amount of energy which such systems have is proportional to the temperature. However, at any particular temperature, some systems will have less than the average energy and a very small number, very much more energy. Only the systems with exceptionally high energy will be able to pass from one low region to the other, and the fraction of the systems which have this unusual amount of energy increases very rapidly with the temperature. This fact accounts for the rough empirical rule that the reaction rate doubles with a 10° increase in temperature.

In order to make an actual calculation of the reaction rate of the reaction $H_2 + J_2 = 2HJ$, say, the fundamental idea of Gibbs may be utilized. Imagine a reaction vessel with a great number of H_2 and J_2 molecules. Let us subdivide the vessel into small compartments, each containing one single H_2 and J_2 molecule. The number of collisions between H_2 and J_2 molecules will be still the same as in the original vessel. However, every H_2 can react with one J_2 only so that we need to consider the configuration space of one pair of molecules only, instead of considering the coordinates of all the molecules simultaneously.

The instantaneous state in each compartment can be represented by a point in the configuration space. There will be one point in the configuration space for each compartment. As the molecules move in each compartment, the corresponding points in the configuration space will swarm like people in a mountainous region. To begin with, only one valley in configuration space is populated. The people scurry around apparently aimlessly. Most of them have too little energy to rise much above the floor of the valley. Even those who have enough energy to emerge from the crowd will go uphill at any arbitrary place and only a few of the lucky ones will strike the path that leads into the neighboring valley. The number of these successful ones is all that concerns us. Their number gives us the number of reactions in our original vessel.

We can count these lucky people by multiplying their density at the top of the pass with the velocity with which they are traveling. Account must be taken, of course, of the fact that some of them which passed the crest of the hill, having encountered some obstacle, return without having descended into the new valley.

Both the density of the people in the pass and their velocity are given by standard formulas of statistical mechanics. Indeed, the velocity depends only on the temperature and the mass of the atoms involved. The density depends only on the temperature, the density of population in the valley and the height of the pass above the valley floor. Thus the whole reaction rate depends only on the nature of the landscape in the immediate neighborhood of the pass, the nature of the valley floor and the temperature. It has practically nothing to do, however, with the intervening country. The paths leading from one valley to the other may traverse many lower passes and intermediate valleys. All this will have little effect on the density of the highest pass and thus practically no effect on the reaction rate.

The intermediate valleys correspond to the intermediate compounds, frequently isolated by skillful chemists. These give us important information on the topography of the landscape. The mere fact that they can be isolated shows, however, that they inhabit low valleys and not the critical pass where density determines the rate of reaction.

Of all the quantities entering into the calculation of reaction rates the height of the pass above the valley is responsible for the greatest uncertainty. Except for a few cases, so far, it has always been necessary to derive this value from the

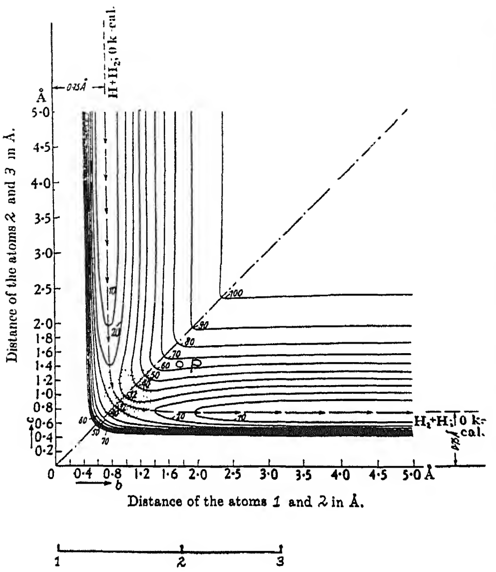

FIG. 1. THE CIRCLE P IN THE FIGURE ABOVE CORRESPONDS TO THE LINEAR CONFIGURATION OF THE THREE ATOMS AS INDICATED BELOW. THE FIGURE ABOVE REPRESENTS THE ENERGY SURFACE FOR ALL LINEAR CONFIGURATIONS. THE HEIGHT OF THE SURFACE ABOVE THE PLANE OF THE FIGURE IS CHARACTERIZED BY THE CONTOUR LINES, AS IS USUAL ON MAPS.

experiments on reaction rates themselves. An improvement of our knowledge of the

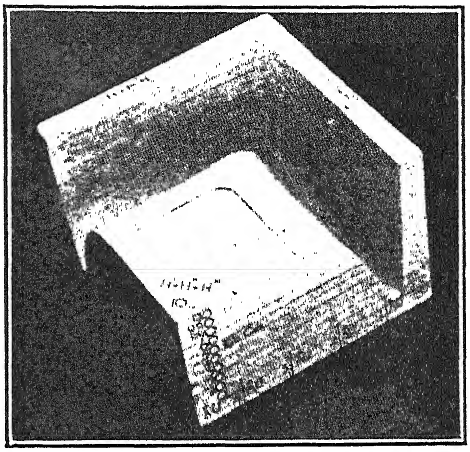

FIG. 2. PHOTOGRAPHIC PICTURE OF THE LANDSCAPE OF FIG. 1, TAKEN FROM THE WORK OF C. F. GOODEVE.

landscape is highly desirable, therefore. This will be achieved, no doubt, in two different ways—partly by a further improvement in the theoretical calculation of such surfaces, partly also by experimental investigations from which empirical rules can be derived. The question of absolute rates thus reduces to the construction of the appropriate energy surfaces, after which it becomes a simple problem of arithmetic.

WILLIAM MORTON WHEELER

THE PROGRESS OF SCIENCE

WILLIAM MORTON WHEELER

The sudden death of Wheeler, on April 19, seems in a manner incredible. For so many years he has been part of our entomological world, and we had not contemplated a time when we should have to do without him. In a true sense, we need not think of such a time, for his works remain and will retain their essential vitality far into the future. Posterity will read them with profit and admiration, but we are sorry for those who did not know the living, energetic, enthusiastic Wheeler as we have known him in the flesh. I think of the summer of 1906, when Wheeler came out to Colorado to take part in an expedition to Florissant. We were hunting fossil insects, and digging a trench in the volcanic shales, uncovered many remarkable species, which have since been described. But Wheeler also looked for living ants, and we sprawled on the ground, while he showed us the red *Polyergus* and described to us its slave-making operations. He had an almost uncanny knowledge of the ants, and could recognize most of the North American kinds at a glance. Thus we spent the days hunting and observing, and in the evenings discussed many matters far into the night. In Chicago, in Texas, at the American Museum in New York, and in later days at Harvard, Wheeler has made his great contributions, not only to the literature of his subject, but also to the enrichment of the lives of numerous disciples, many of whom are now doing important work. It has been impossible to escape his influence, for, as was once said of another man, when he did not reach the people, he reached the people who reached the people.

Wheeler's best *apologia,* so far as it concerns his work on ants, is found in the preface to his classical work "Ants," published in 1910. He says: "My work began in an endeavor to increase our systematic knowledge of the North American ants, but I was fascinated by the activities of these insects and soon saw the advantage of studying their taxonomy and ethology conjointly. This method, which was, indeed, unavoidable, has greatly retarded the appearance of the present work, for it was impossible to write about the behavior of many of our most interesting forms till their taxonomic status had been definitely settled. On the other hand, I could find no satisfaction in devoting all my energies to collecting and labelling specimens without stopping to observe the many surprising ethological facts that were at the same time thrusting themselves upon my attention. My observations have now covered so much of our fauna that I shall soon be able to publish a systematic monograph, which will, I hope, enable the student to form a rapid acquaintance with our ants."

Alas! the monograph has not appeared, at least not in its entirety, though Wheeler has published revisions of several of the more important genera.

Trying to define Wheeler's type of mind, it may perhaps be said that it was restless and expansive. There are college professors who are content to reach a certain state of perfection, and let it go at that, teaching the same things, in the same way, year after year. But Wheeler always appeared to be going somewhere, and thus when he took up the study of American ants, he soon found himself involved with the ants of the world on the one hand, and the whole field of comparative psychology on the other. This led him to visit Australia to see the remarkable and primitive ant-fauna of that country, and to write at great length on

the ants of Africa, of Central and South America and of many parts of Asia. Every one of his papers, no matter how technical or taxonomic, was illuminated by comments on evolution, geographical distribution and similar broad topics.

There existed a parallel yet different type of man in Switzerland. This was Forel, the great European myrmecologist, who also concerned himself with psychology, and was in fact an authority of note on diseases of the mind. Forel and Wheeler were in active cooperation for many years. Wheeler once described to me some of the incidents of his visit to Forel, and told with relish the parting comment of the Swiss, "Wheeler, you are outwardly calm, but inwardly perturbed. I am outwardly perturbed, but inwardly calm." Wheeler declared that this was essentially true; as we think of it now, he combined in one individual a high development of the emotional and intellectual faculties. One can imagine that he might have been a great religious or political leader, had he not adopted the principles and practices of the scientific worker.

Wheeler not only had an admirable English style, but was quite at home with German and French. It was thus possible for him in 1925 to act as exchange professor at the University of Paris, and while there he saw the unpublished manuscript of Réaumur. This eighteenth century worker was a pioneer of a type to instantly win Wheeler's admiration, and the result was the publication, in English, of a translation of Réaumur's treatise on ants. This includes numerous critical annotations, and an account of the life and work of Réaumur.

The main facts concerning Wheeler's life will be told elsewhere. Born at Milwaukee in 1865, he early came under German influences, attending a German-American college. He took up the study of entomology very early, being first attracted to it by observing some burying-beetles working under a dead animal. After a time, he became the happy possessor of Say's "Entomology," which contained descriptions of many North American insects. He once told me that, when very young, he found numerous beetles which were not in Say, and innocently proceeded to describe them, supposing them to be new. This effort was of course never published, but it is of interest as showing at an early age the habit of going beyond the books, reaching out to nature for new revelations of her works.

Some of his early work, which would indeed have given him a permanent place in zoology, if he had done nothing else, was in the field of embryology. That he gave up such laboratory studies and turned to the observation of living things showed the strong and constant trend of his mind. When, in later years, he wrote many severely taxonomic papers, they were always illuminated by the thought of vital processes, which in the light of his great knowledge could be inferred even from cabinet specimens.

We should like to think that Wheeler will have worthy successors. But one of the most eminent American zoologists recently expressed to me his regret that, as it appeared to him, the young men were growing up to be admirable and even marvelous technicians, but with little breadth of view. It is through the development of this technique, and the intensive work of the laboratories, that great advances are now being made in the field of biology. Yet the work of Wheeler, looking toward the processes of nature as seen in the field, and the results of those processes as expressed in classification, calls us to a vast undertaking which seems to have no end, in which all zealous students may have a part. As we proceed, we learn many things, while at the same time meeting innumerable unsolved problems, calling us onward.

No laboratory work, no experimental methods, can take the place of such studies. Taught by Wheeler, we can in new ways go to the ant, and learn of its ways, and be wise.

T. D. A. COCKERELL

THE ANNUAL MEETING OF THE NATIONAL ACADEMY OF SCIENCES

THE National Academy of Sciences held its seventy-fourth annual meeting on April 26, 27 and 28, at the academy building in Washington, D. C. One hundred and thirty-one members were present—nearly one half of the total membership. At this time of year Washington is especially beautiful and attracts many visitors who come to enjoy the city and to take part in meetings and conventions of different groups. During the last week in April approximately one thousand scientists attend the meetings of the National Academy of Sciences, the American Geophysical Union, the American Physical Society, the American Meteorological Society and the Institute of Radio Engineers with the American Section of the International Scientific Radio Union. The stimulus given by these and other gatherings and by personal contacts and conferences is an important aid to progress in science.

The scientific sessions of the recent annual meeting were well attended and the papers aroused interest and discussion. The distribution, among the sciences, of the 43 papers on the program was: mathematics, 3; physics, 7; chemistry, 3; crystallography, 1; paleontology, 1; oceanography, 2; genetics, 6; pathology, 1; physiology, 4; embryology, 2; biochemistry, 3; psychology, 2; anthropology, 1; biographical memoirs, 6. Members of the academy read 29 papers; non-members, 14 papers.

Brief mention of several of the papers will serve to indicate the variety and

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scope of the subjects presented. Dr. O. E. Schotté, of Amherst College, discussed "Embryonic Induction in Regenerating Tissue," as illustrated by experiments on transplanting embryonic eye-cups of *Rana pipiens* below the skin of regenerating tails of large tadpoles of the same species. These eye-cups induced the neighboring tissues to differentiate into typical lenses and eventually to develop adjacent organs as neoformations, such as ear vescicles with labyrinth and mouth cavities on the tadpole tail. Dr. Schotté concluded that "every cell possesses potentially everything to produce any type of tissue or organ." Dr. Simon Flexner, of the Rockefeller Institute for Medical Research, described in a paper on "Immunity and Reinfection in Experimental Poliomyelitis" the effects of reinoculation of monkeys which had recovered from attacks of poliomyelitis (infantile paralysis) experimentally induced. The monkeys were found to be subject to reinfection by the nasal route, thus indicating that vaccination, in the case of monkeys, does not give the protection that recovery from the natural disease affords. "It is thus apparent that the two immune states in poliomyelitis, one based on recovery from an attack of the disease and the other symptomless reaction to virus injections are not identical. They do agree in that under both sets of conditions antibodies usually appear in the blood."

Investigations by Dr. H. G. Barbour, of Yale University, on the effects of the presence of heavy water (deuterium oxide) in mice on the nervous system were described in a paper on "Sympathomimetic Influence of Deuterium Oxide." Dr. Barbour and associates found that, when half the body water of a mouse is replaced by heavy water, the animal dies; "when, however, the body water is but one fifth saturated with heavy water the mouse survives, but lives at a faster rate; metabolism is increased by some 20 per cent., usually with eleva-

tion of body temperature. The results obtained indicate that the effects may be due to excessive stimulation of sympathetic nerve mechanisms (sympathomimetic action)."

Drs. E. N. Harvey, G. A. Hobart, III, and A. L. Loomis, of Princeton University and the Loomis Laboratory, reported upon "Cerebral Processes during Sleep as Studied by Human Brain Potentials." They discovered that the electrical potentials of the brain differ greatly in pattern from person to person; at one extreme, the wave frequency is 10 per second; at the other, from 30 to 40 per second. In an individual of the 10-beat type profound changes in rhythm occur during a period of sleep; as he falls asleep the 10-second rhythm is interrupted and is replaced by large random potentials; deep sleep is characterized by random potentials plus short bursts of 14 per second rhythm. These phenomena enable the observer to distinguish the states of sleep in persons of this type.

Dr. F. G. Benedict, of the Carnegie Institution of Washington, described experiments made on geese and mice to ascertain if body fat is a factor in heat production. He found that the daily heat production and the heat production per gram of dry protein of a fat mouse weighing 60 grams was more than twice that of a 20-gram albino mouse. Similar tests on geese indicate that body fat plays a part in metabolism. "The obese must pay in calories for their fat loads."

Drs. H. W. Haggard and L. A. Greenberg, of Yale University, discussed "The effects of alcohol as influenced by blood sugar." They found that the intoxicating and lethal effects of grain alcohol are due to its action on the brain and that the concentration of alcohol in the brain depends upon that in the blood. The increase of sugar in the blood after a meal greatly lessens the pharmacological effect of alcohol. In rats, which are fed sugar, the toxicity of alcohol is influenced in-

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versely by the amount of sugar in the blood. This modifying effect of sugar upon the action of alcohol is connected with the combustion of alcohol in the tissues. Methyl alcohol and ether are not appreciably burned in the body, and the concentration of sugar in the blood does not influence their lethal concentrations. Evidence has been obtained indicating that man reacts similarly.

Drs. G. L. Streeter, E. A. Park and Deborah Jackson, of the Carnegie Institution of Washington, in a study of the "Hereditary Vulnerability of Dietary Effects in the Development of Bone," found that when young rats at the end of the first month are placed for three weeks on a rachitic diet and then returned to a normal diet the effect of this treatment persists throughout the life of the rat and is transmitted to its young. Following 14 generations of such selection and inbreeding this strain of rats reacts more severely to a rachitic diet than do non-treated rats. "From such experiments we can understand why under equally unfavorable conditions the children in some families acquire rickets, while others do not."

Drs. L. H. Germer and K. H. Storks, of the Bell Telephone Laboratories, investigated the "Structure of Langmuir-Blodgett Films of Stearic Acid" by preparing multiple molecular layers of stearic acid upon metal blocks by the Blodgett method. They found that electrons scattered from such built-up surface films produce diffraction patterns consisting of segments of sharp lines normal to the specimen and arranged along diffuse inclined bands which are parallel and equally spaced. The stearic acid is formed into large monoclinic crystals and arranged with a long crystallographic axis parallel to the long axis of the individual molecules and inclined 57° to the surface plane, and with two orthogonal axes of lengths 9.4A and 5.0A in the sur-

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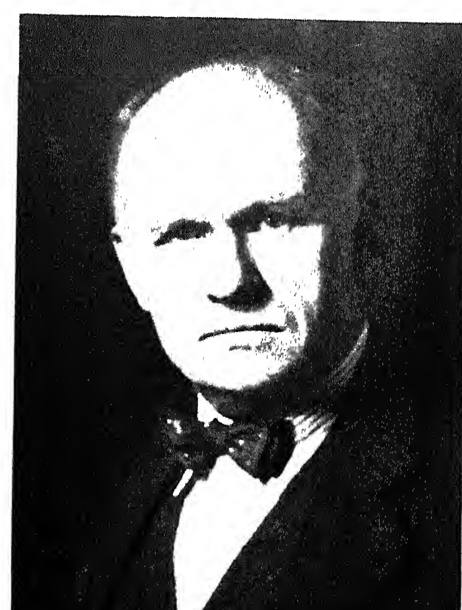

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face plane, in agreement with that of single crystals of stearic acid.

Dr. G. H. Parker, of Harvard University, in a study of neohumors, which are hormones produced by the secretory portions of the nervous system or by glands immediately associated with this system, found that neohumors from obvious glands are soluble in water and are carried by the blood (hydrohumors); those from nerve terminals are insoluble in water but soluble in ether or oil (lipohumors), and are local in action, while hydrohumors are general in action. It is thus evident that "neohumors, contrary to the older view, are an extremely diverse and numerous set of substance."

Dr. Warren H. Lewis, of the Carnegie Institution of Washington, reported upon the part played by macrophages which come from the large mononuclear white blood cells and are scattered in the tissue spaces throughout the body. They serve not only as scavengers, but as "pinocytes" (drinking cells) and probably maintain the body fluids in proper condition by "digesting and thus modifying the tissue fluids which bathe most of the cells of the body."

From studies on the "Plankton and Radiolarian Ooze in Paleozoic Formations of New York," Dr. R. Ruedemann, of the New York State Museum, concluded that "radiolarian chert represents radiolarian ooze formed at a depth corresponding to that at which the ooze is formed to-day and that the bottom of the Appalachian geosyncline sank at times to abyssal depths."

Drs. M. A. Tuve, L. R. Hafstad and N. P. Heydenburg, of the Carnegie Institution of Washington, in a statement on "The structural forces of atomic nuclei" showed from measurements on the angular scattering of a beam of protons passing through hydrogen gas that the Coulomb law of repulsion fails at very close distances. Their measurements in-

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dicate that the proton-proton forces are nearly identical with the proton-neutron and the neutron-neutron forces; these three attractive forces are the structural basis for the formation of the nuclei of the chemical elements. Observations in the region of 200 to 500 kilovolts prove that "the forces between two protons change from repulsion to attraction as they are brought close together."

Drs. P. A. Levene and Alexandre Rothen, of the Rockefeller Institute for Medical Research, discussed the "Mechanism of the Reaction of Substitution and Walden Inversion" and proved by experiments with secondary normal aliphatic alcohols and corresponding amines and the three corresponding chlorides, bromides, and iodides that, with certain substitutions on the optically active carbon atom, "one substitution by a negative ion takes place on the positive, the other on the negative end of a dipole."

The Monday evening public lecture was given by Dr. G. H. Whipple, of the School of Medicine and Dentistry, University of Rochester, New York, on the subject "The Romance of Hemoglobin." Dr. Whipple has studied the production of new red cells in the blood of dogs made anemic by bleeding under controlled experimental conditions and has measured the production of hemoglobin as influenced by various factors. He has found that when red cells wear out in the circulation they disintegrate and the hemoglobin or red coloring matter of the blood breaks down into three fractions: iron, a pigment radicle (hemin), and the large globin fraction or protein part. The liver and bone marrow are the chief agencies for the production of new red cells and hemoglobin. Diet is an important factor by which we may control hemoglobin production. Liver gives a maximal production of hemoglobin; green vegetables are in a mid position; fruits may be active (apricots, prunes, peaches) or may be inert (berries). Dr. Whipple's interest-

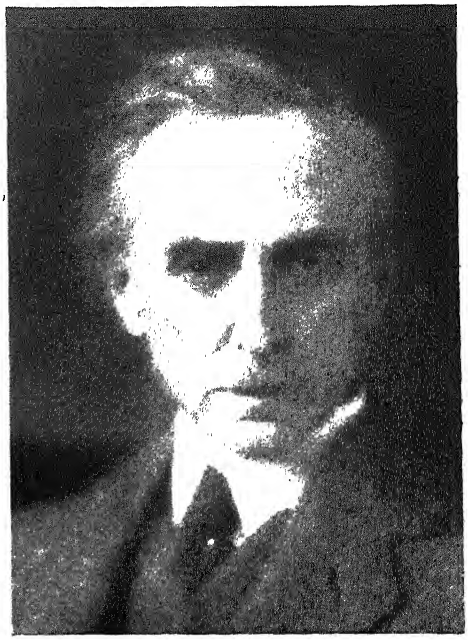
ing lecture on this important but difficult subject was enthusiastically received by the many listeners.

On Monday afternoon the academy members and guests visited the Folger Shakespeare Library on invitation of its director, Dr. Joseph Quincy Adams, who showed the group over the library, explained its purposes and exhibited many of the rare books and treasures from the Elizabethan period in the Folger collection. The visit was extremely interesting and was greatly appreciated by the academy members.

At the annual dinner President Lillie delivered, at the request of the committee on arrangements, a brief address on the status of the academy and on its accomplishments during the past year. He mentioned briefly the special problems on which the government has sought the advice of the academy since the last annual meeting. These requests are referred to the Government Relations and Science Advisory Committee for consideration as they are received. Each problem is studied and reported upon by a special subcommittee appointed for the purpose; its report is transmitted by the president of the academy direct to the government department or agency which sought the advice. This procedure has functioned satisfactorily and with good results in the variety of problems thus far investigated.

Following the president's address, four medals were presented: (1) The Agassiz Medal for Oceanography, awarded to Dr. Martin Knudsen, of the University of Copenhagen; (2) the Henry Draper Medal, awarded to Dr. C. E. Kenneth Mees, of the Eastman Kodak Company; (3) the James Craig Watson Medal, awarded to Dr. Ernest William Brown, Yale University Observatory; (4) the Mary Clark Thompson Medal, awarded to Dr. Amadeus William Grabau, of the National University of Peking, China.

At the business session the membership limit was raised from 300 to 350. Dr. Arthur L. Day, of the Carnegie Institu-



DR. LEO LOEB

EMERITUS PROFESSOR OF PATHOLOGY, WASHINGTON UNIVERSITY.

DR. EDWARD C. TOLMAN

PROFESSOR OF PSYCHOLOGY, UNIVERSITY OF CALIFORNIA

tion of Washington, was reelected vice-president for a period of four years. Dr. H. S. Jennings, of the Johns Hopkins University, was reelected a member of the council, and Dr. O. Veblen, of the Institute for Advanced Study, Princeton, was elected a member of the council, each for a period of three years. Dr. August Krogh, professor of zoophysiology at the University of Copenhagen, Denmark, was elected a foreign associate of the academy. Fifteen men, whose portraits are here reproduced with the exception of Dr. Seth B. Nicholson of the Mount Wilson Observatory, were elected to membership in the academy.

The present membership of the academy is 299; there are 40 foreign associates, with a limit of 50.

The autumn meeting of the academy will be held this year on October 25, 26 and 27 at the University of Rochester.

F. E. Wright,
Home Secretary

THE DENVER MEETING OF THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE

In June this year, scientists from the East and from the West, from the North and from the South, will gather in Denver, Colorado, to attend and take part in the one hundredth meeting of the American Association for the Advancement of Science. The formal sessions will begin on Monday, June 21, and continue during the remainder of the week.

Not only will the Denver meeting be the hundredth one of the association, but it will be the first in which both the Pacific Division and the Southwestern Division have joined with the parent organization. These divisions of the association will be responsible for some of the most important features of its programs. Of the principal evening addresses, one will be delivered by Dr. Herbert M. Evans, president of the Pacific Division, and the other will be delivered by Dr. A. E. Douglass, representing the Southwestern Division. Since the association is American in the continental sense, distinguished Canadian scientists will participate, as usual, in its meeting this summer. Indeed, the meeting will be in a wider sense international, for Dr. Nevil V. Sidgwick, a distinguished representative of the British Association for the Advancement of Science, will deliver the Maiben Lecture.

The 18,000 active members of the association are organized into 15 special sections which, together with 161 affiliated and associated societies, cover practically all pure and applied science. Consequently, the subjects on the programs of the meeting will range from the mysterious cosmic rays to the "dust bowl" problem, from solar storms and the aurora borealis to loathsome leprosy. And there will be papers by specialists on prehistoric Indians, at one extreme, and on current scientific developments in methods of education, at the other. Engineers will discuss and visit great works in concrete and steel, while mathematicians and economists will produce equally interesting and valuable structures in the realms of statistics. Geologists will look down into the earth, and astronomers will turn their eyes upward toward the stars. Even though religion finds no formal place on the programs of the meeting, under the deep blue Colorado skies and in the presence of its white-crowned mountains, many a visitor will feel with Byron—

Not vainly did the early Persian make
His altar the high places, and the peak
Of earth-o'ergazing mountains, and thus take
A fit and unwalled temple, there to seek
The Spirit, in whose honour shrines are weak,
Upreared of human hands. Come, and compare
Columns and idol-dwellings, Goth or Greek,
With Nature's realms of worship, earth and air,
Nor fix on fond abodes to circumscribe thy
    prayer.

It is fitting that the centenary meeting of the association should be held at Denver, for this fine city is on the roof of the continent and almost at its center. It is the terminus of six principal railroads, which offer 30-day summer excursion rates at less than one and three quarters cents per mile; and leading into the city from every direction are perfect concrete roads. At the very feet of some of the most majestic mountains in North America, it rests on a fertile plain made refreshingly and delightfully green by irrigation. Denver is a city of homes and broad tree-lined streets and beautiful parks. It is a center of education and culture. Its early carefree spirit, born on the range and in the mine, has been succeeded by the culture and refinement of schools and churches and libraries without its losing the cordial hospitality characteristic of the frontier.

Denver is the center from which one may take a remarkable number and variety of mountain excursions. Four times daily transportation companies take visitors over the circle of Denver Mountain Parks, including visits to historic Golden, once the capital of Colorado, and passing over Lariat Trail by Sensation Point, Windy Saddle and Hairpin Curve to the top of Lookout Mountain, on which is located the tomb of "Buffalo Bill," the most romantic character of the days of thundering buffaloes and Indians on the warpath. Even more sensational is the 138-mile Mt. Evans-Echo Lake excursion, made daily, as well as several other comparable trips. And, finally, there is the incomparable Rocky Mountain National Park 250-mile Circle Tour, during which the visitor drives several miles along the continental divide at an elevation of more than two miles. At other times he winds his way through long canyons cut deep by ice and water and in the cool shade of which columbines grow. He spends a night at Grand Lake at an altitude of 8,370 feet, and on the next day passes through Arapaho National Forest, by the western portal of six-mile-long Moffat Tunnel, over Berthoud Pass, at an altitude of 11,300 feet, and back to Denver through Clear Creek Canyon.

Visitors to the meeting of the association in Denver this June will have not only feasts for the mind at its scientific sessions, but feasts for the soul in its inspiring excursions.

F. R. MOULTON,
Permanent Secretary

THE MEMPHIS MEETINGS ON EXPERIMENTAL BIOLOGY

GOING to a Southern city for the first time in its history, the Federation of American Societies for Experimental Biology held its annual meetings in Memphis, Tennessee, from April 22 to 24. The American Institute of Nutrition gave its usual program of papers in advance of the main sessions, on April 21. The registration was the third largest in the history of the federation, totaling 1,106. The meetings were held in the Hotel Peabody, whose commodious mezzanine floor was able to accommodate all ten of the sectional meetings which progressed simultaneously, permitting a more easy movement from one program to another than has been possible in other recent conventions of the federation.

The sessions were crowded with reports of new advances in the fields of physiology, biochemistry, pharmacology and pathology. Nearly 500 papers were presented. High lights of the meetings included the discussion of the electroencephalogram by Dr. Hallowell Davis, of Harvard Medical School, the review of the nutritive significance of the amino-acids by Dr. W. C. Rose, of the University of Illinois, and the address of Dr. Thorvald Madsen, chairman of the health

committee of the League of Nations, who described the work of his committee in setting up international biological standards.

Papers presented before the sectional meetings covered a vast territory, from the description of a new factor in the Vitamin-B complex responsible for black hair color, made by Dr. Agnes Fay Morgan, of the University of California, through reports of an electrical wave generated at the time of ovulation, reported by Drs. Reboul, Friedgood and Davis, of Harvard University, to the first demonstration of secretory nerves to the liver, described by Drs. Tanturi and Ivy, of the Northwestern University Medical School. The sectional meetings were more than usually well attended and were characterized by vigorous discussions. A thousand people crowded the convention hall of the Peabody on Thursday morning, April 22, to listen to papers presented before the joint sessions of the four federated societies, over which Dr. Alphonse Dochez, federation chairman, presided.

The usual program of demonstrations was given on the afternoon of the 23rd, in the laboratories of the College of Medicine, University of Tennessee, which acted as host for the meetings. Local arrangements were made by a committee headed by Dr. O. W. Hyman, chairman, and Dr. T. P. Nash, secretary. Tea was served in the new University Center, by the ladies of the faculty.

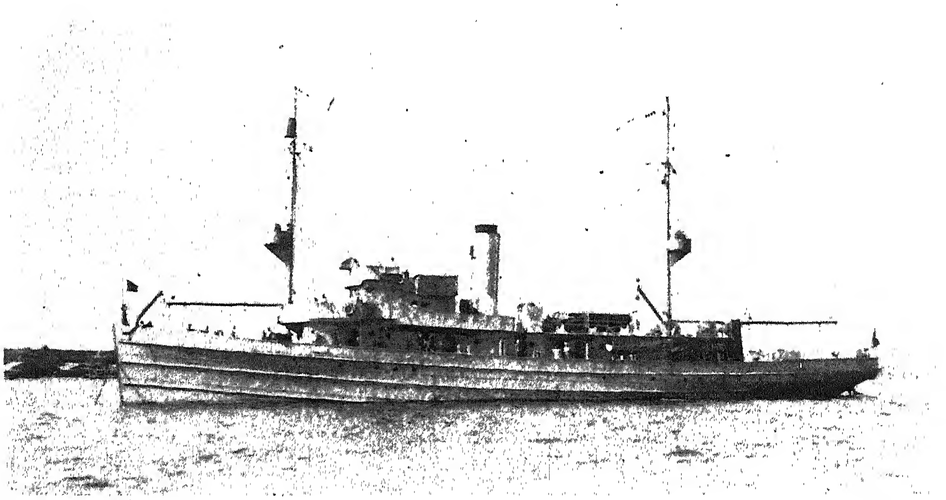
The members of the federation were given opportunities to visit the great cotton warehouses and other industries connected with the cotton business, to inspect the extensive slum clearance projects and to view the levee system which protects the city and surrounding low lands from flood waters.

WILLIAM R. AMBERSON

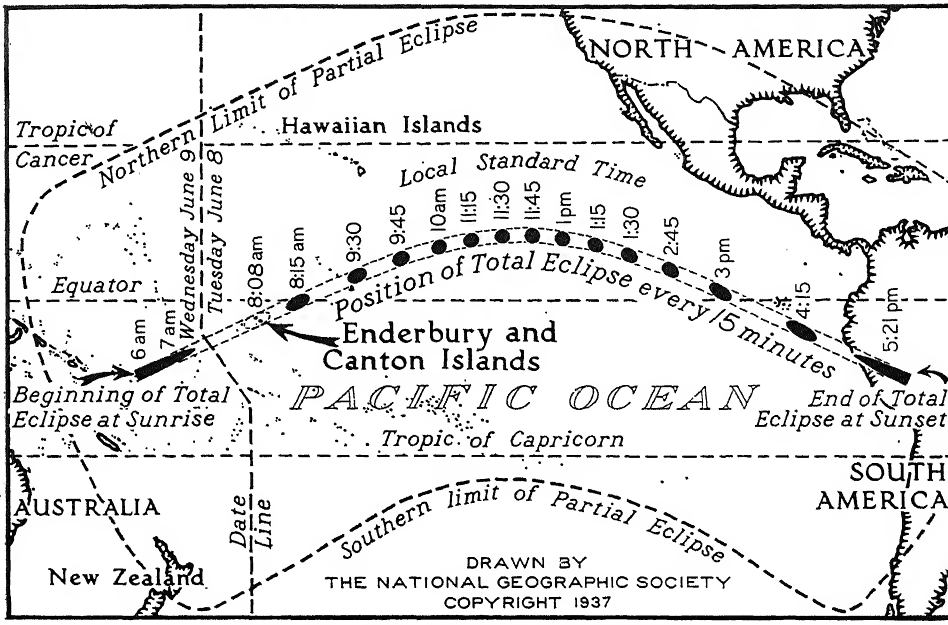
THE ECLIPSE EXPEDITION OF THE NATIONAL GEOGRAPHIC SOCIETY AND THE UNITED STATES NAVY

THE total solar eclipse of June 8, 1937, longest in 1,238 years, will be observed from a "desert island" in the Pacific Ocean by a large expedition under joint auspices of the National Geographic Society and the United States Navy, equipped for many phases of eclipse observation. The expedition sailed from Honolulu on May 6.

Although the path of totality will



THE *U. S. S. AVOCET*, WHICH CONDUCTED THE EXPEDITION TO THE PHOENIX ISLANDS.



MAP OF THE PATH OF THE ECLIPSE.

sweep 8,800 miles across the Pacific from near the New Hebrides to the coast of Peru, there are only two small coral atolls in this entire distance which offer suitable conditions for eclipse observation. These are Canton and Enderbury Islands, part of the Phoenix Group, 1,900 miles southwest of Hawaii and just south of the Equator. Because the islands are so little known, it was necessary for the National Geographic-Navy Expedition to choose which of the islands to occupy after arriving in the vicinity and observing local conditions.

Both islands are not more than 25 feet above sea level, are uninhabited and have central lagoons. Canton is only nine miles long and four miles wide, while Enderbury is about one tenth as large. Considerable guano has been collected from the Phoenix Group in the past, and coconut palms have been planted on some of the islands.

The scientific program of the expedition includes spectrographic observations of the corona and the chromosphere; black and white photographs of the corona with various exposures and light filters; motion pictures of the entire eclipse; timing of the contacts of the sun and moon; measurements of the total light of the corona and of its polarization; and observations of the effect of the eclipse on the ionosphere as indicated by radio signals sent and received inside the band of totality. The eclipse colors will be recorded both by natural color photography and by an artist who will make a painting of the phenomenon.

A unique feature of the expedition will be a series of radio broadcasts from the island telling of the preparations and everyday life of the expedition, and culminating in a description of the eclipse itself.

The scientific leader of the expedition is Dr. S. A. Mitchell, director of the Leander McCormick Observatory, University of Virginia, and veteran of nine previous eclipse expeditions. Captain J. F. Hellweg, U. S. N., Ret., superintendent of the U. S. Naval Observatory, is in charge of the Navy's participation.

Other members of the party are: Dr. Paul A. McNally, S.J., director, Georgetown College Observatory; Dr. Irvine C.

Gardner, National Bureau of Standards; Dr. Floyd K. Richtmyer, dean of the Graduate School, Cornell University; Dr. Theodore Dunham, Jr., Mount Wilson Observatory; Charles G. Thompson, president, Foundation for Astrophysical Research; John E. Willis, U. S. Naval Observatory; Charles Bittinger, artist, Washington, D. C.; Richard H. Stewart, staff representative, National Geographic Society; Walter Brown and M. S. Adams, radio engineers, and George Hicks, radio announcer, all of the National Broadcasting Company. Lieutenant Thomas B. Williamson, U. S. N., is in command of the *U. S. S. Avocet,* which conducted the expedition to the Phoenix Islands; and Dr. Herman A. Gross, U. S. N., has been assigned to look after the health of the party.

Dr. Mitchell and Dr. Richtmyer are members of the National Academy of Sciences and Dr. Mitchell is president of the Commission on Eclipses of the International Astronomical Union.

Dr. Mitchell and Dr. Dunham will record the spectrum of the corona and the flash spectrum, the latter being visible briefly just after totality begins and just before it ends. Dr. McNally will photograph the corona, using the same two cameras he employed successfully during the solar eclipse of 1932, with various light filters. Dr. Gardner will make both black and white and natural color photographs with a 19-foot camera of his own design, with which he obtained excellent results during the eclipse last June in the U. S. S. R. Dr. Gardner has equipped his telescopic camera with a rotating disk with portions cut away in such a fashion that the faint, outer portion of the corona can be given a much longer exposure than the bright portion visible near the rim of the moon.

Dr. Richtmyer will measure the coronal light and its polarization. Mr. Thompson will cooperate with Dr. Dunham in spectrographic observations. The Naval Observatory representatives will devote special attention to timing the contacts of the sun and moon. The records of these times will be extremely useful in the observatory's function as time-keeper for the nation. Mr. Bittinger will paint the eclipse and Mr. Stewart will make motion pictures of the entire event.

The *Avocet* is a former mine sweeper which has been converted to a seaplane tender. The ship will be anchored offshore throughout the stay of the expedition on location. Members of its crew will be detailed to assist the scientific party when it sets up camp on one of the islands. In the three weeks between arrival at the islands and the occurrence of the eclipse, the party planned to lay cement foundations for instruments, to determine the island's exact location and to make other preparations.

The width of the path of totality will vary from 125 miles at either end to 155 miles in the center, and will be about 140 miles in the Phoenix Islands. Duration of totality will be 4 minutes and 9 seconds on Enderbury Island, and three minutes and 35 seconds on Canton. The maximum duration, 7 minutes and 4 seconds, will occur at noon at a point in the open ocean nearly 1,500 miles from the nearest land. The path of totality will cross the International Date Line in the mid-Pacific, so that the eclipse actually will begin on June 9 and end on June 8. Totality will commence on Canton Island at 7:39 A.M. local civil time, and on Enderbury at 7:42. This corresponds approximately to 2:15 P.M. Eastern Standard Time. The altitude of the sun above the horizon at mid-totality will be about 22 degrees on both islands.

The unusual duration of this eclipse, the longest since 699 A.D., is due to a coincidence of three factors: It occurs near July 1, when the sun is at its greatest distance from the earth; it occurs at a time of the month when the moon is closest to the earth; and the moon's shadow in this instance falls near the Equator.

G. G.

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